[redacted]

AEC Category: HEALTH AND SAFETY

[redacted]

CEX-59.4.24

CIVIL EFFECTS STUDY

AERORADIOACTIVITY SURVEY AND GEOLOGY OF THE GNOME (CARLSBAD) AREA, NEW MEXICO AND TEXAS (ARMS-I)

Jules A. MacKallor

Issuance Date: January 1965

CIVIL EFFECTS TEST OPERATIONS
U.S. ATOMIC ENERGY COMMISSION

This report has been reproduced directly from the best available copy.

Printed in USA. Price $1.00. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Va.

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

AERORADIOACTIVITY SURVEY AND GEOLOGY OF THE GNOME (CARLSBAD) AREA, NEW MEXICO AND TEXAS (ARMS-I)

By

Jules A. MacKallor

Approved by: Director
U. S. Geological Survey

Approved by: L. J. DEAL
Chief
Civil Effects Branch

U. S. Geological Survey

and

Division of Biology and Medicine, USAEC
February 1963

NOTICE

ABSTRACT

An aeroradioactivity survey of about 7000 square miles around the GNOME test site near Carlsbad, N. Mex., was made by the U. S. Geological Survey in cooperation with the Division of Biology and Medicine, U. S. Atomic Energy Commission. The project was flown along east-west flight lines approximately 500 ft above the ground. Flight lines were one mile apart in the central part of the area and two miles apart elsewhere.

Aeroradioactivity contacts shown on a 1:250,000 map delineate areas of similar radioactivity. The radioactivity values, to which a cosmic correction has been applied, are shown in counts per second (cps), and have been corrected for deviations from the 500 ft surveying altitude.

The GNOME area includes parts of three physiographic regions: the Llano Estacado and Pecos lowlands sections of the Great Plains, and the foothills and mountains. The Guadalupe Mountains lie west of Carlsbad, and the Delaware Mountains lie along the southwestern edge of the area.

The radioactivity of the GNOME area is low and ranges from 50 to 600 cps. The Llano Estacado portion of the area ranges from 100 to 400 cps; the Pecos lowlands from 50 to 600 cps; and the foothills and mountains from 200 to 600 cps.

Rocks of Permian age crop out extensively in the Guadalupe and the Delaware Mountains. The predominantly carbonate rocks in the Guadalupe Mountains have a radioactivity of 100 to 600 cps, but most are between 200 and 400 cps. The predominantly clastic rocks in the Delaware Mountains have a radioactivity of 250 to 550 cps, but most are between 350 and 500 cps.

Rocks of Permian age crop out in the Pecos lowlands and have been divided into the Castile and the Rustler Formations. They are composed principally of anhydrite and carbonate rocks; but the Rustler contains some sandstone and siltstone. The Castile ranges from 50 to 450 cps, but most is 100 to 300 cps; the Rustler ranges from 200 to 500 cps, but most is 200 to 300 cps.

The Ogallala Formation of Tertiary age was deposited by coalescing streams and consists mostly of sand, silt, and gravel. This formation is the bedrock of the Llano Estacado, and small outliers of the Ogallala occur in the Pecos lowlands. The radioactivity of the formation is 100 to 400 cps. A distinct radioactivity contact coincides with Mescalero Ridge, the Ogallala Formation east of the ridge being 100 cps higher than the Quaternary sand to the west.

ABSTRACT (Continued)

About 50 percent of the GNOME area is covered with surficial material of Quaternary age. The alluvium and terrace deposits of the Pecos River have a radioactivity of 300 to 600 cps and form a conspicuous radioactivity high. Most of the Quaternary west of the Pecos River valley consists of alluvium from small streams and of outwash from the mountains and has a radioactivity of 200 to 500 cps. East of the Pecos River valley the Quaternary deposits consist of alluvium and sand dunes, and the radioactivity ranges from 100 to 300 cps, but most is 100 to 200 cps.

The radioactivity of Crow Flats, a large playa, is more than 150 cps higher than its drainage area, and there is some evidence that playas in general are more radioactive than their drainage areas.

CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

FIGURES

PLATE

AERORADIOACTIVITY SURVEY AND GEOLOGY OF THE GNOME (CARLSBAD) AREA, NEW MEXICO AND TEXAS (ARMS-I)

1. INTRODUCTION

1.1 Location, Purpose, and Scope of Survey

An aeroradioactivity survey of an area of about 7000 square miles centered at the GNOME site near Carlsbad, N. Mex. (Fig. 1), was made by the U. S. Geological Survey in cooperation with the Division of Biology and Medicine, U. S. Atomic Energy Commission as part of the Aerial Radiological Measurement Surveys (ARMS-I) program. The area surveyed lies between 33° and 31° 30' north latitude and 103° 00' and 104° 45' west longitude, but the steep front of the Guadalupe Mountains precluded surveying some of the area west of 104° 30'. The survey was flown between April 21 and May 12, 1960.

The GNOME area is arid to semiarid. The mean annual rainfall is from about 10 to slightly more than 15 in. Vegetation is sparse because of the limited rainfall and high rate of evaporation. Only the mountainous areas are forested. Extensive areas of sand dunes are practically bare of vegetation.

The survey is part of a nationwide program to obtain data on the existing gamma radioactivity for areas around nuclear facilities. The data provide information that can be used to detect any changes in radioactivity that might result from nuclear testing, AEC operations, or radiation accidents. The data can be used as an aid to geologic interpretation and mapping, but the geologic usefulness of the GNOME data is limited because there is little contrast in the radioactivity of many of the formations.

1.2 Airborne Surveying Procedure

The survey was made with scintillation-detection equipment installed in a twin-engine aircraft. The surveyed area was traversed by parallel east-west flight lines approximately 100 miles long. For the central 30 percent of the area, the flight line spacing

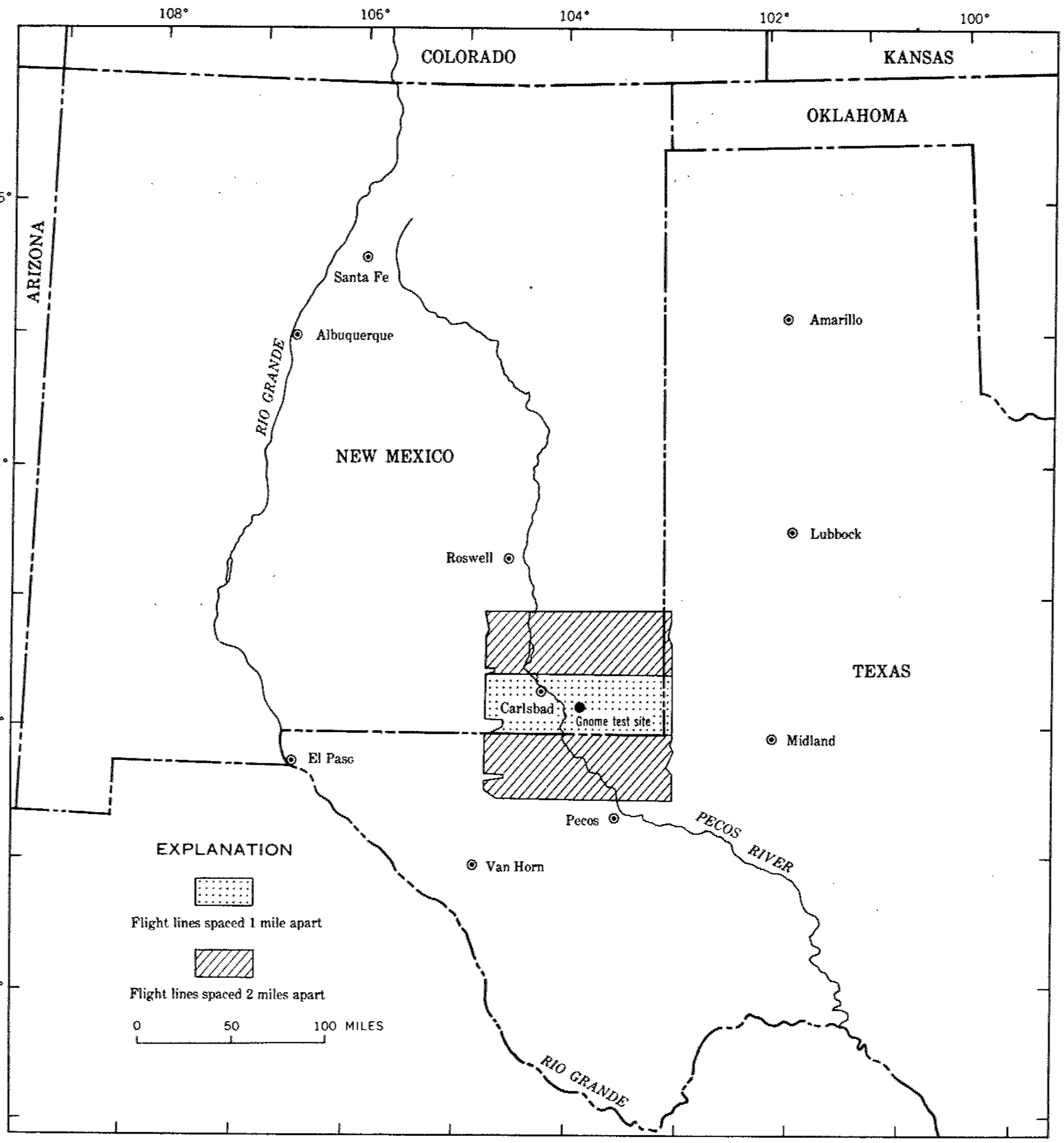


Fig. 1—Index map showing location of area surveyed.

was 1 mile, and for the remainder of the area the spacing was 2 miles (Fig. 1). The aircraft maintained an approximate altitude of 500 ft above the ground and an average air speed of 150 mph. County road maps and topographic maps were used for pilot guidance. The flight path of the aircraft was recorded by a gyrostabilized continuous-strip-film camera, and the distance of the aircraft above the ground was measured by a continuously recording radar altimeter. Fiducial markings, which provide a common reference for the radioactivity and altimeter charts and the film, were made with an electromechanical edge-mark system operated by the flight observer whenever the aircraft passed over recognizable features on the ground.

1.3 Scintillation Detection Equipment

The gamma-radiation equipment used by the Geological Survey was designed by the Health Physics Division of the Oak Ridge National Laboratory and has been described in detail by Davis and Reinhardt[1,2]. They describe the sensitivity of the equipment in several ways, one being (Ref. 1, p. 717) "the count rate for a dose rate of one microroentgen per hour due to radium gamma rays is 225 cps (counts per second)." For simulated sources, they state that "The count rates at 500 ft equivalent to a ground reading of 1 μ/hr for Cs^{137} and Co^{60} plane sources are 25 and 18 counts/sec, respectively" (Ref. 2, p. 239). Kermit Larsen[3] determined that a count rate of about 77,000 cps would be recorded by the Geological Survey equipment 500 ft above an infinite area of fallout that produced a gamma-ray flux of 1 milliroentgen per hour (mr/hr) 3 ft above the ground.

A diagram of the airborne radioactivity survey equipment is shown on Figure 2. The detecting element consists of six thallium-activated sodium iodide crystals, 4 in. in diameter and 2 in. thick, and six photomultiplier tubes connected in parallel. The signal from the detecting element is fed through amplification stages to a pulse-height discriminator that is set to accept only pulses originating from gamma radiations with energies greater than 50 thousand electron volts (kev). A 1-second time constant is normally used. The signal from the discriminator is fed to two rate meters. One rate meter feeds a circuit that records total (uncompensated) radioactivity on a graphic milliammeter. The signal from the other rate meter is recorded by a circuit that includes a variable resistance, which is controlled by the radar altimeter servomechanism, thereby approximately compensating the circuit for deviations from the 500 ft surveying altitude.

The crystals are shielded on the sides by $\frac{1}{2}$ in. of lead to eliminate the influence of radium-dial instruments in the aircraft.

At an elevation of 500 ft the effective area of response is about 1000 ft in diameter, and the radioactivity recorded is assumed to be an average of the radioactivity received within the area. Theoretical aspects of the area of response are discussed by Sakakura[4].

The area of response of the radar altimeter is smaller than the effective area of response of the scintillation detection equipment, and there may be overcompensation above narrow valleys and ridges. Nevertheless, the corrections for altitude deviations in the area

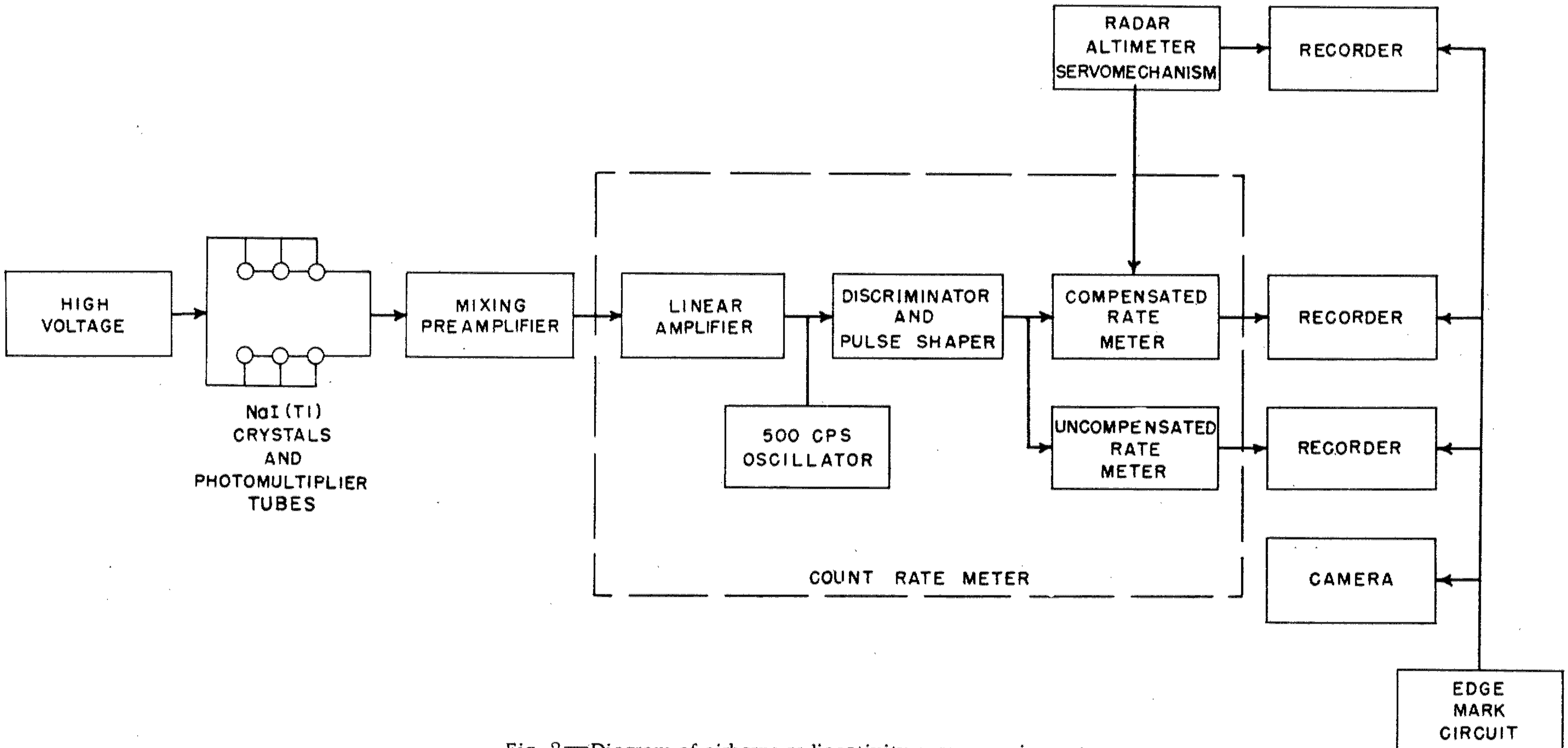


Fig. 2—Diagram of airborne radioactivity survey equipment.

surveyed are within the limits of accuracy required, and meaningful radioactivity measurements are obtained over rough terrain.

1.4 Compilation of Aeroradioactivity Data

The flight line locations from the strip film were plotted on base maps, a combination of topographic maps and county road maps at various scales. The compensated radioactivity profiles were examined, and the radioactivity breaks (changes in level of radioactivity) and the values to the nearest 50 cps were marked on the profiles. Several profiles were examined simultaneously to correlate the breaks from line to line. The location of the breaks, the radioactivity in cps along the flight lines, and the radioactivity correlations between lines were plotted on transparent overlays of the base maps. The overlays were reduced photographically to a scale of 1:250,000, and the major radioactivity breaks were transferred to the 1:250,000-scale topographic map series of the Geological Survey. The final map (Pl. 1) shows lines where the radioactivity changes, the aeroradioactivity in cps, and major cultural and geographic features. This map is also published in the Geological Survey's Geophysical Investigations Map Series[5].

The range of radioactivity shown for each unit on Plate 1 includes most, but not 100 percent, of the values recorded. Within some units there is a slight difference in the radioactivity from one part of the unit to the other. In such cases, the differences are indicated by the values on Plate 1. For example in the extreme northeast corner of the mapped area, there is a radioactivity unit that ranges from 200 to 300 cps. In Yoakum County, Tex., the values recorded ranged from 200 to 300 cps, but in the extreme northern part of Gaines County, Tex., the values recorded range from 250 to 300 cps, and further south the values decreased slightly.

1.5 Theoretical Considerations of Gamma-ray Surveying

The gamma-ray flux at 500 ft above the ground has three principal sources: cosmic radiation, radionuclides in the air, and radionuclides in the surficial layer of the ground. These sources are discussed by Gregory[6].

The cosmic background at 2000 ft above the ground was measured at the beginning and end of each day's surveying, and a specific number of cps, about nine-tenths of the radioactivity recorded at 2000 ft, was removed from the altitude-compensated radioactivity circuit. At 2000 ft the gamma radiation from normal surficial material is negligible. The cosmic correction for the surveying altitude of 500 ft is slightly less than the cosmic background recorded because the cosmic rays have to travel through an additional 1500 ft of air to reach the surveying altitude. During the GNOME survey the cosmic background recorded at 2000 ft ranged from 280 to 420 cps with a mean of 330 cps. The mean daily variation was less than 40 cps, the maximum daily variation was 90 cps.

The effects of radionuclides in the air are difficult to evaluate but apparently are negligible most of the time, and if proper precautions are taken, do not greatly reduce the value of aeroradioactivity surveys. Dust and industrial smoke may contribute minor amounts of radionuclides to the air. At times airborne debris from atomic testing must greatly affect airborne radioactivity surveys, but the effects should be recognizable. The amount of radon in the atmosphere varies greatly and is determined by the surficial material and by atmospheric conditions. The effects of varying amounts of radon can be minimized if surveys are not flown during periods of atmospheric inversion or during and immediately after thundershowers.

The compensated radioactivity values are primarily a measure of the gamma radiation from natural radionuclides within the upper few inches of surficial material below the aircraft. Data from periodic surveys by the Geological Survey in several states indicate that fallout is a negligible part of the present-day background radioactivity[7], and there is no indication that fallout affected the GNOME survey.

The distribution and quantity of natural radioactive elements in the surficial material are determined by the radioactive elements in the parent rock and by changes brought about by soil-forming processes, both organic and inorganic. A fundamental consideration in studying the radioactivity of soil is whether it is a residual soil, formed by weathering of rock <u>in situ</u>, or whether the soil has been transported, in which case it <u>may have</u> been derived from rocks different from the underlying bedrock. Both types of soil are common in the GNOME area.

Although there are other naturally occurring radioactive elements, only uranium, thorium, potassium, and their decay products are significant to aeroradioactivity surveys. The importance of uranium and thorium is well known, but the importance of potassium sometimes is overlooked. Russell[8] in discussing gamma-ray logs of oil wells, says that the use of such logs might be a failure if dependent only on uranium and thorium. Potassium consists of three isotopes, of which K^{40} is a strong gamma-emitter; the other two isotopes are nonradioactive. The ratio of K^{40} to total potassium is only 1:9,000 according to Bramley and Brewer[9]; but by laboratory studies of gamma-rays only, Spicer[10] determined that the strength of potassium to uranium was 1:496, which is in close agreement with the theoretical value. Moxham[11] believes that a factor of 2.5×10^{-4} should be used to convert total potassium to equivalent uranium for the Geological Survey's airborne gamma radioactivity surveys. Radiations with a large absorption coefficient (low energy) are attenuated more rapidly than those with a small absorption coefficient (Ref. 6, p. 18). Since gamma radiations from the uranium series are mostly low energy, they undergo a relatively greater attentuation than the radiations from thorium or potassium.

Although the potassium to uranium to thorium ratio, as well as the percentages of these elements, varies greatly in rocks, certain generalizations can be made. Shales normally contain more uranium, thorium, and potassium than chemical precipitates such as limestone, dolomite, and anhydrite. Although a pure quartz sandstone has a very low radioactivity, most sandstones have a radioactivity intermediate between limestone and shale. Felsic rocks, such as granite and rhyolite, normally contain more uranium, potassium, and thorium than mafic rocks, such as gabbro and basalt.

1.6 Reliability of Data

An excellent check on the reliability of the compensated radioactivity can be obtained whenever the aircraft flies over a large body of water. Since water has practically no radioactivity and absorbs gamma-rays, the compensated data should record close to 0 cps if the atmosphere does not contain an abnormal amount of radioactive particles. Radioactivity of 0 to 150 cps was obtained over the large lakes or reservoirs in the GNOME area; the higher values were recorded near the edge of the lakes where the detecting equipment was being affected by the proximity of land.

A short test line, a portion of a regular survey line, was flown at the beginning and end of each day's surveying and the same test line was used for several day's surveying so that there is a check on the consistency of the data.

On May 11 and 12, 1960, the last two days of surveying, the radioactivity recorded along the test line was 50 to 100 cps higher than previously recorded for the same test line. The area covered by the last two day's surveying (flight lines 77 to 99) consists of the area south of Red Bluff Lake (Pl. 1). The radioactivity values appeared to be excessively high in comparison to that measured over geologically similar areas north of Red Bluff Lake. The radioactivity values as shown on Plate 1 for the area south of the lake are 100 cps lower than the values actually recorded. Even after lowering the values, some of the area south of Red Bluff Lake still appears to be about 50 cps too high in comparison with the area to the north.

Comparison of test lines justified lowering the data by 100 cps, but the reason that the test line recorded higher radioactivity for the last two days of surveying is not known. The record shows that the radioactivity equipment was properly calibrated for those days, and was functioning properly. It is possible but unlikely that the area was contaminated with a trace amount of high-level fallout. One explanation is that the amount of radon released from the ground to the atmosphere increased slightly, but the author has no meteorological data to substantiate this hypothesis.

2. PHYSIOGRAPHY

The GNOME area is separable into three physiographic regions: the Llano Estacado (Staked Plains) and Pecos lowlands sections of the Great Plains province, and the foothills and mountains. Plate 1 shows the boundaries between the regions.

The northeastern and east-central part of the GNOME area is part of the Llano Estacado. The Llano Estacado is separated from the Pecos lowlands by Mescalero Ridge. In the northern part of the area this ridge forms a deep escarpment 500 to 800 ft high facing southwest. South of Hobbs, N. Mex., the escarpment is much less pronounced and trends almost south.

The surface of the Llano Estacado in the GNOME area is generally flat, but there are some knobs and buttes of more resistant rock. Drainage occurs through a poorly developed network of intermittent streams. Bedrock for most of the area consists of the flat-lying Ogallala Formation. Although outcrops are not scarce, the Ogallala is mostly covered with a thin mantle of caliche or soil, and large areas are covered with sand dunes. Harper and Smith[12] present a good description of the surficial deposits and land forms.

The Pecos lowlands includes the area west of the Llano Estacado and east of the foothills and mountains. The Pecos River valley, including alluvial terraces on the west bank, is in places considerably more than a mile wide and much of this rich land is irrigated. Reservoirs have been constructed at favorable sites. Most of the irrigated land lies west of the river; in many places high bluffs border the east bank of the Pecos.

The Pecos lowlands, exclusive of the irrigated strip along the river, is barren and desolate, but the flatness of the region is interrupted in places by low ridges and buttes of Triassic and Cretaceous rocks.

Outcrops of bedrock are relatively scarce. Most of the surficial material is transported, but some, especially west of the Pecos River, is residual, consisting of the insoluble residues of the Permian rocks. The soil contains much caliche and gypsum. Many square miles are covered with sand dunes, and other large areas are pitted with numerous sink holes.

In that part of the Pecos lowlands east of the river, the surface drainage pattern is poorly developed, and much of the runoff is discharged into small closed depressions or playas. The playas have a slightly higher radioactivity than their drainage area. For a further discussion see Section 5.

The mountains and foothills border the Pecos lowlands on the west. Southwest of Carlsbad, the very steep escarpment of the Guadalupe Mountains precluded surveying some of the mountains, but the northern part of the Guadalupe Mountains and the Delaware Mountains and outlying foothills (Pl. 1) are not so rugged. Bedrock of various lithologies is well exposed in many canyons and on many steep slopes.

3. GENERALIZED AERORADIOACTIVITY

The radioactivity of the GNOME area ranges from about 50 to 600 cps, which is low in comparison to other ARMS-I areas.

The Llano Estacado portion of the project has a radioactivity of 100 to 400 cps, and most of this area is 250 to 350 cps.

The Pecos River valley has a radioactivity of 300 to 600 cps; most of the valley is 400 to 500 cps. The lower radioactivity was recorded for the valley around Carlsbad, and the higher radioactivity was recorded north of Lake McMillan.

That part of the Pecos lowlands east of the river valley has a radioactivity of 50 to 400 cps, mostly within the 150 to 300 cps range. West of the river valley the Pecos lowlands has a radioactivity of 50 to 500 cps. North and west of Carlsbad the radioactivity is mostly 400 to 500 cps; and south and west of Carlsbad it is mostly 250 to 400 cps.

The foothills and mountains in the western part of the project have a radioactivity of 200 to 600 cps. In the Guadalupe Mountains the radioactivity is 200 to 600 cps, but most is 200 to 400 cps. In the Delaware Mountains the radioactivity ranges from 250 to 550 cps, but most is 350 to 500 cps.

4. CORRELATION OF GEOLOGY TO AERORADIOACTIVITY

Figure 3 shows the generalized aeroradioactivity, and Figure 4 shows the generalized geology of the GNOME area. The geology was compiled from the 1:380,160 geologic map of southeastern New Mexico[13] and from the 1:500,000 geologic map of Texas[14].

The rocks in the Guadalupe Mountains have been studied by a number of geologists and have been mapped in great detail. Figure 4 shows only the more extensive units in the Guadalupe Mountains.

Approximately one-half of the GNOME area is shown as Quaternary, which includes a variety of surficial deposits such as alluvium and sand. For part, but not all, of the GNOME area the different types of Quaternary deposits have been mapped, but are not shown separately on Figure 4.

4.1 Permian System

The Permian System in the region consists of the Wolfcamp, Leonard, Guadalupe, and Ochoa Series, but only the last two have extensive outcrops in the GNOME area. The New Mexico Geological Society[15] has published a chart showing the correlations made by various authors of the Permian in southeastern New Mexico and the adjacent part of west Texas.

4.1.1 Guadalupe Series

The stratigraphy of the Guadalupe Series is quite complex. In addition to being divided into a number of formations, these marine rocks are grouped into three different environmental zones or facies. The reef facies[16] separates the shelf or back reef facies in the Guadalupe Mountains from the fore-reef or Delaware Basin facies. The reef facies[13] consists of the Capitan Limestone and the underlying Goat Seep Limestone, which does not outcrop in the GNOME area. The Capitan forms a conspicuous escarpment along the eastern front of the Guadalupe Mountains, but the outcrop is too narrow to show on Figure 4 so the Capitan is included with the Tansill Formation. The Capitan grades laterally into the Tansill, Yates,

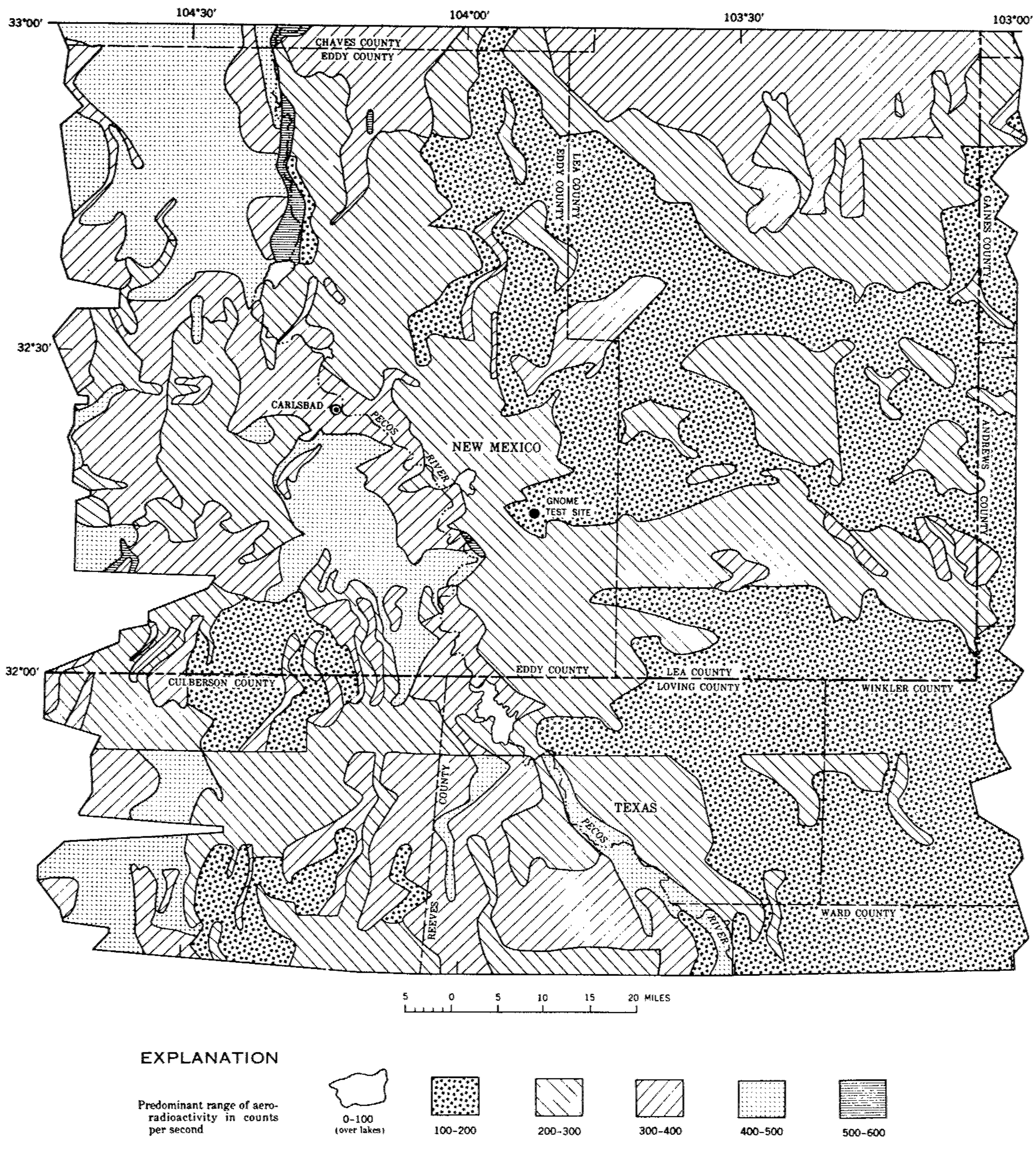


Fig. 3—Generalized aeroradioactivity map of GNOME area, New Mexico and Texas.

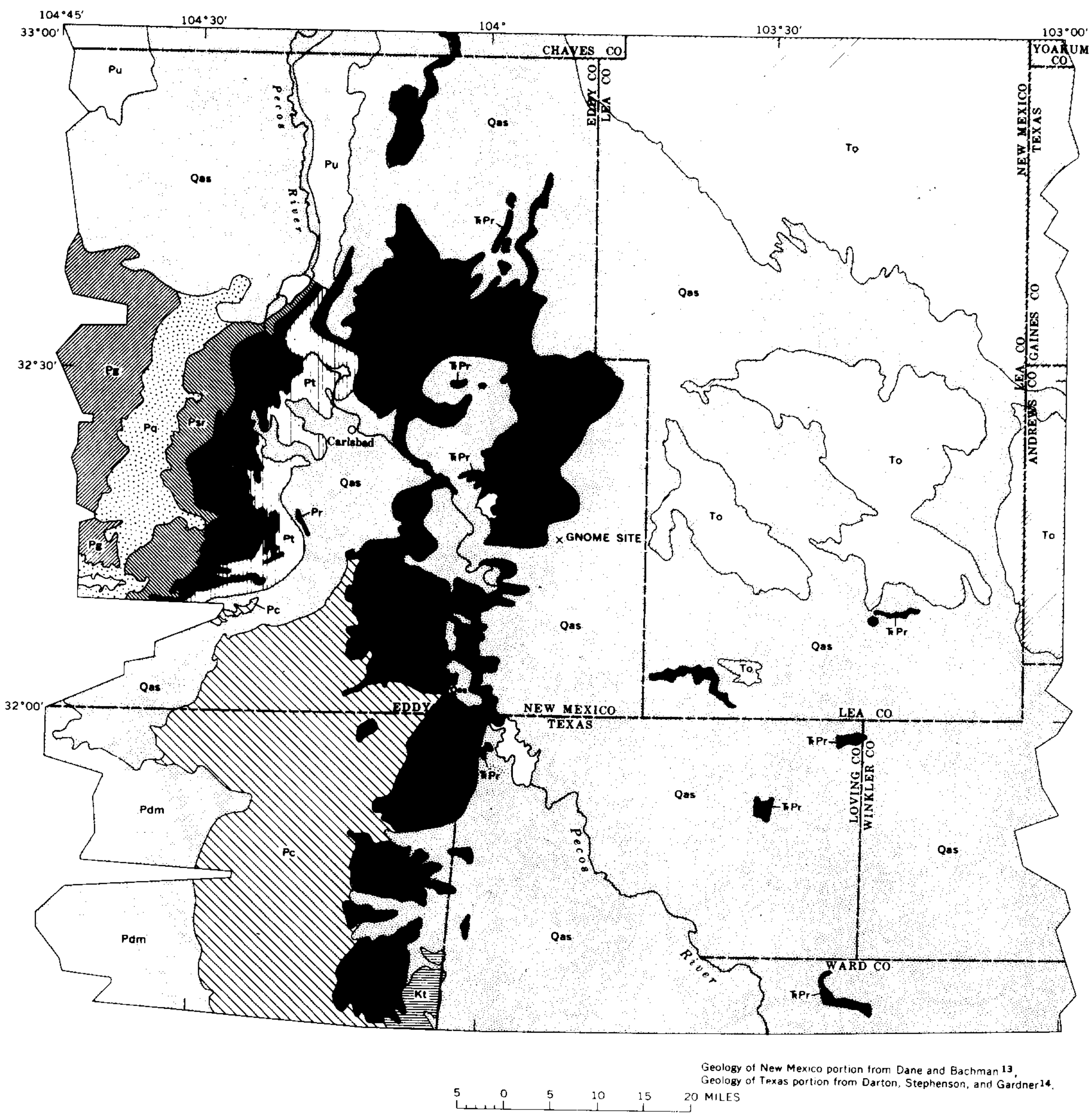


Fig. 4 — Generalized geologic map of GNOME area, New Mexico and Texas.

(1)

EXPLANATION

QUATERNARY — *Pleistocene to Recent*

Qas

Alluvium and sand

Alluvium west of the Pecos River valley; mostly sand east of the Pecos River valley in New Mexico, some sand in Winkler and Andrews Counties, Texas

TERTIARY — *Pliocene*

To

Ogallala Formation

A continental deposit of sand and gravel, locally with calcareous cement. Contains beds and lenses of clay, silt, volcanic ash, and limestone

CRETACEOUS — *Lower Cretaceous*

Kt

Trinity Group

Sandstone

PERMIAN AND TRIASSIC

Redbeds

Sandstone and siltstone, some shale and conglomerate, mostly red, some gray. Includes Dewey Lake Redbeds of Late Permian age and Dockum Group of Late Triassic age

PERMIAN

Ochoa Series

Rustler Formation

Thin-bedded dolomite and anhydrite, some siltstone

Pc

Castile Formation

Anhydrite and limestone

Guadalupe Series

Pt

Tansill Formation

Carbonate rocks, some siltstone, sandstone, and anhydrite

Yates Formation

Dolomite, sandstone, and siltstone

Psr

Seven Rivers Formation

Limestone, dolomite, and anhydrite

SHELF FACIES

Pu

Anhydrite, carbonate rocks, and siltstone

Pq

Queen Formation

Sandstone, siltstone, and dolomite

Pg

Grayburg Formation

Carbonate rocks, sandstone, and siltstone

DELAWARE BASIN FACIES

Pdm

Delaware Mountain Group

Sandstone and limestone

Contact

2

and Seven Rivers Formations. On Figure 4 the rocks of the shelf or back reef are shown by five formations and one unit of undifferentiated rocks; the rocks of the Delaware Basin are shown by the Delaware Mountain Group.

4.1.1.1 Grayburg Formation

The Grayburg Formation crops out along the extreme western edge of the GNOME area west of Carlsbad. A very minor amount of the underlying limestone of the San Andres Limestone and a sandstone tongue of the Cherry Canyon Formation[17] are included with the Grayburg on Figure 4. The Grayburg is about 450 ft thick. It consists chiefly of dolomitic beds 3 to 18 in. thick but contains some beds of limestone, siltstone, and sandstone.

The radioactivity of the Grayburg Formation ranges from 200 to 500 cps, and about half of the formation is 300 to 400 cps.

4.1.1.2 Queen Formation

The Queen Formation crops out in a north-south band east of and adjacent to the area of Grayburg in the northwestern part of the GNOME area. The Queen is about 400 ft thick. The lower part of the formation consists of interbedded dolomite and sandstone as does the underlying Grayburg, but sandstone is relatively more abundant in the Queen[17]. The upper 100 ft of Queen is predominantly siltstone.

The radioactivity of the Queen Formation is between 300 and 450 cps, with the exception of one small area where it is as high as 600 cps. The slightly higher radioactivity of the Queen in comparison to the Grayburg is explained by the higher percentage of siltstone and sandstone in the Queen contrasted to the higher percentage of dolomite in the Grayburg.

4.1.1.3 Seven Rivers Formation

The Seven Rivers Formation occurs in a belt adjacent to and east of the Queen Formation. The Seven Rivers Formation is 450 to 500 ft thick and consists of limestone, dolomite, and anhydrite, which near the surface weathers to gypsum.

The radioactivity of the Seven Rivers Formation is mostly 200 to 300 cps, but about one-fourth of its area is 300 to 400 cps. The geologic contact between the siltstone in the upper part of the Queen Formation and the carbonate rocks and gypsum of the Seven Rivers is fairly well marked by a radioactivity contact (Figs. 3 and 4).

4.1.1.4 Yates Formation

The Yates Formation occurs in a north-south belt adjacent to and east of the Seven Rivers Formation. The Yates consists of 250 to 300 ft of alternating beds of dolomite, siltstone, and sandstone.

The radioactivity of two-thirds of the area of Yates Formation is 200 to 300 cps, and one-third is 300 to 400 cps.

4.1.1.5 Tansill Formation

The Tansill Formation forms a band east of and adjacent to the Yates Formation. The Tansill normally is 100 to 150 ft thick; but where it grades into the Capitan Limestone, it is more than 300 ft thick[18]. The Tansill is composed chiefly of thin beds of dolomite and limestone but contains a few beds of siltstone and fine-grained sandstone. Locally thin beds of anhydrite are interlayered with the carbonate rocks.

South of Carlsbad the radioactivity of the Tansill Formation is mostly 200 to 300 cps but north of Carlsbad some of the Tansill is 300 to 400 cps. South of Carlsbad the contact between the Tansill Formation and the adjacent Quaternary deposit of 400 to 500 cps correlates with a prominent radioactivity contact.

4.1.1.6 Undifferentiated Rocks of Guadalupe Age

Figure 4 shows two areas in which the rocks of Guadalupe age have not been differentiated. The principal rock types are gypsum, anhydrite, dolomite, limestone, and siltstone. In the extreme northwest corner of the GNOME area these rocks correspond at least in part to the Grayburg Formation. These undifferentiated rocks have a radioactivity of 300 to 500 cps, mostly from 400 to 500 cps.

A second area of undifferentiated rocks is just east of the Pecos River in the northern part of the GNOME area. These rocks are equivalent to the Seven Rivers, Yates, and Tansill Formations. In this area beds equivalent in age to the Tansill Formation contain anhydrite. The radioactivity of this area is 100 to 400 cps, mostly 200 to 300 cps. In general the radioactivity is highest in the northern and lowest in the southern part of this unit.

4.1.1.7 Delaware Mountain Group

The rocks of the Delaware Mountain Group crop out in the Delaware Mountains in the southwest corner of the GNOME area. These rocks belong to the Delaware Basin facies and are age equivalents to the rocks of the shelf or back reef facies previously described. According to King[19] the Delaware Mountain Group is about 2700 ft thick in the northern Delaware Mountains. This group is predominantly fine-grained sandstone but contains some beds of limestone.

The radioactivity of the Delaware Mountain Group within the GNOME area is 250 to 550 cps, and more than one-half is between 400 and 500 cps. The sandstones of this unit have a higher radioactivity than the predominantly carbonate rocks of equivalent age in the Guadalupe Mountains.

4.1.2 Ochoa Series

In the GNOME area the principal formations of the Ochoa Series, in order of decreasing age, are the Castile, the Salado, and the Rustler. These formations consist mostly of anhydrite, salt, and limestone.

The uppermost beds of the Ochoa Series belong to the Dewey Lake Redbeds, but on Figure 4 the Dewey Lake is included with redbeds of Triassic age.

The Salado Formation is known chiefly from the subsurface and is not shown on Figure 4. It is predominantly salt and anhydrite and contains important deposits of potash minerals. The Salado was originally included with the Castile, but Lang[20] divided the salt section into a lower unit, essentially the Castile Formation of Richardson[21], and an upper unit, the Salado Formation. According to King[22], an unconformity separates the Salado from the Rustler, which accounts for most of the Salado being missing from outcrop in the Gypsum Plain and Rustler Hills in the northeastern corner of Culberson County, Tex.

4.1.2.1 Castile Formation

Within the GNOME area the Castile Formation crops out only in Culberson County, Tex., and southern Eddy County, N. Mex. The Castile is more than 1800 ft thick[23] and consists principally of anhydrite, which at the surface alters to gypsum. The formation also contains halite, which is too soluble to occur in outcrop, and limestone. Clay- and silt-sized particles tend to be concentrated at the surface as the more soluble constituents are leached.

Practically all the area of the Castile Formation has a radioactivity from 100 to 300 cps, but in a few places values as low as 50 cps and as high as 450 cps were recorded. The contact between the Castile Formation on the east and the Delaware Mountain Group on the west in Culberson County, Tex., coincides with a change in radioactivity where the clastic rocks of the Delaware Mountain Group are 100 to 200 cps higher than the Castile rocks.

4.1.2.2 Rustler Formation

The Rustler Formation crops out in an irregular band in the Pecos lowlands. In the southern part of the area, the Rustler is in contact with the Castile to the west, but the Rustler extends further north than the outcrops of Castile.

The Rustler Formation is dominantly anhydrite and salt but contains two dolomite and several siltstone and sandstone members[24]. The formation has a maximum thickness of nearly 400 ft (Ref. 22, p. 91).

The radioactivity of the Rustler ranges from 200 to 500 cps, but more than 50 percent of the area of Rustler is 200 to 300 cps. The slightly higher percentage of clastics in the Rustler explains the slightly higher radioactivity when compared to the Castile Formation, but the contacts of the Rustler with the Castile and other formations are not marked by a noticeable change in radioactivity.

4.1.2.3 Redbeds

The redbed unit of Figure 4 includes the Dewey Lake Redbeds of Late Permian age and other redbeds, probably part of the Dockum Group of Late Triassic age. These rocks crop out in several small areas in the Pecos lowlands where they occur as erosional remnants on the Rustler Formation.

The redbeds consist chiefly of fine-grained sandstones and siltstones but contain some shale and conglomerate. Anhydrite is a common cementing material. Most of these clastic rocks are red but some are gray. Although the upper part of these redbeds has been removed by erosion in the GNOME area, the thickness is more than 100 ft.

The radioactivity of the redbeds as shown in Figures 3 and 4 is 100 to 400 cps. At the scale of these maps and the flight line spacing of this project, the redbeds cannot be separated from the Quaternary deposits.

The redbeds commonly cap small buttes extending above the surficial deposits of the Pecos lowlands. Although both the redbeds and the surficial deposits have a low radioactivity, a very detailed survey (see Section 6.) indicated that the areas of redbeds can be separated from the surficial material on the basis of radioactivity.

4.2 Cretaceous System

4.2.1 Trinity Group

Rocks of the Trinity Group of Early Cretaceous age remain as erosional remanents in the extreme southern part of the GNOME area along the boundary between Reeves and Culberson Counties, Tex. As shown by King[25], the Cretaceous rocks at this location are sandstone, and are the basal beds of the Trinity Group. The Trinity rocks are marine sediments that were deposited on an irregular land surface. The sand was continually reworked by waves and currents as the advancing Trinity sea progressed landward so that the basal sand consists of clean quartz[26]. The radioactivity of the Trinity sand is 150 to 300 cps.

4.3 Tertiary System

4.3.1 Ogallala Formation

The Ogallala Formation of Pliocene age extends over much of the Great Plains from South Dakota to Texas. The formation ranges in thickness from a featheredge to more than 500 ft[27]. The GNOME area is near the southern limit of the Ogallala. The formation crops out throughout much of the Great Plains province in the northeastern part of the GNOME area (Fig. 4). This province is separated from the Pecos lowlands to the west by Mescalero Ridge (Pl. 1), an escarpment of Ogallala. Several outliers of Ogallala lie west of Mescalero Ridge.

The Ogallala Formation is dominantly sand, silt, and gravel but contains a minor amount of bentonitic clay, diatomaceous marl, and volcanic ash[27]. Lenses of limestone are present. Some of the sediments are unconsolidated; some are indurated. Much of the surface of Ogallala is capped by caliche. The sediments were deposited by coalescing streams; consequently the lithology changes within short distances.

The radioactivity of the Ogallala ranges from 100 to 400 cps. A distinct radioactivity contact coincides with Mescalero Ridge, the Ogallala east of the escarpment being about 100 cps higher than the Quaternary sand to the west. Elsewhere in the GNOME area the Ogallala (Fig. 4) does not correlate closely with radioactivity contacts (Fig. 3). On comparison of the original compensated radioactivity records with the aerial photographs used for pilot's guidance during the survey, small areas of bedrock (Ogallala) are approximately 50 cps higher than adjacent areas of sand.

4.4 Quaternary System

4.4.1 Alluvium and Sand

Slightly more than 50 percent of the GNOME area is covered with surficial material of Quaternary age, which consists mostly of dune sand, alluvium, and outwash from the mountains.

Along the west bank of the Pecos River there is a wide strip of alluvial and terrace deposits, and much of this rich soil is under irrigation. Although some of these sediments are derived locally, the principal source is north of the GNOME area. This alluvium has a radioactivity of 300 to 600 cps, most of the higher radioactivity material being north of Lake McMillan (Pl. 1). The deposits in the Pecos River valley form a conspicuous radioactivity high.

West of the present Pecos River valley most of the surficial Quaternary material consists of alluvium along eastward-flowing small streams and of outwash from the nearby mountains just beyond the western boundary of the area. The radioactivity is 200 to 500 cps. Northwest of Lake McMillan most of the surficial material, exclusive of that in the Pecos River valley, has a radioactivity of 400 to 500 cps.

East of the Pecos River the Quaternary consists of alluvial material and quartz sand. Large areas of many square miles are covered with sand dunes. Most of the dunes apparently are stabilized although vegetation is scanty. Most of these surficial deposits have a radioactivity of only 100 to 200 cps, but some are 200 to 300 cps.

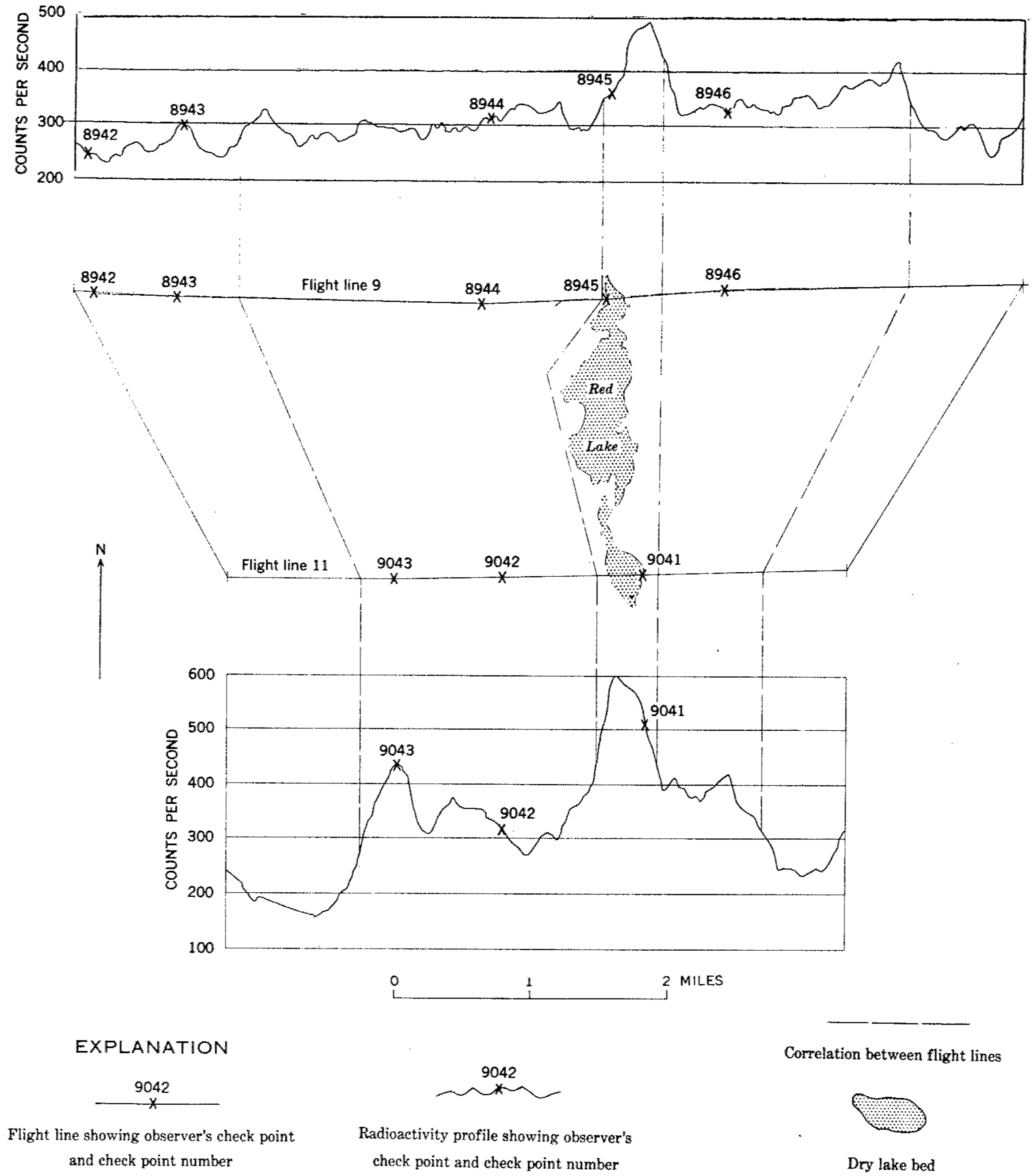


Fig. 5—Aeroradioactivity over Red Lake (Crow Flats), New Mexico.

5. RADIOACTIVITY OF PLAYAS

The playas* in the Pecos lowlands have a higher level of radioactivity than the surrounding areas. The best example is Red Lake (Crow Flats on Pl. 1) about 8 miles east of the Pecos River in northern Eddy County, N. Mex. Figure 5 shows that the radioactivity of this playa is more than 150 cps higher than the surrounding area. San Simon Sink in south-central Lea County, N. Mex., has a slightly higher radioactivity than the surrounding area, but the relation is not clearly defined on Plate 1. There are many other playas in the GNOME area, but most are too small to be evaluated by the flight pattern.

Books[28,29] observed radioactivity highs over large playas in the western Mojave Desert of southern California. Data from the Mojave and from the GNOME area suggests that playas characteristically have a higher radioactivity than their drainage areas.

The typical playa has an accumulation of soluble salts, some of which might contain radioactive elements, that have been leached from the surrounding drainage area and concentrated in the playa by surface water. In addition, surface waters more readily transport finer-sized particles, such as potassium-bearing clay, than larger-sized particles such as quartz sand. Thus an accumulation of soluble salts and clay-sized particles in a playa might increase the radioactivity of the playa relative to its drainage area.

It is logical to assume that if radioactive material from atomic testing fell within an area draining into a playa, the next few heavy rains would cause an accumulation of fallout in the playa. Although the radioactivity of playas is somewhat higher than that of the surrounding areas, the difference is only 100 to 200 cps, and there is no evidence that fallout is responsible for the increased radioactivity.

6. GNOME TEST OF DECEMBER, 1961

An aerial survey was made on Oct. 17 and 18, and another on Dec. 9, 1961, of an area 8 miles north and south by 5 miles east and west, centered at the GNOME test site. The test site is in the Nash Draw quadrangle, N. Mex., in the center of sec. 34, T. 23 S., R. 30 E. An underground nuclear device was detonated on Dec. 10, 1961, and the results of surveys made after the explosion are discussed by Dempsey[30]. Both surveys were made along north-south flight lines one-eighth mile apart. The pre-shot surveys gave similar radioactivity patterns when plotted on aerial photographs.

The data plotted on the photographs shows a definite correlation between geology and radioactivity. The Quaternary surficial material, principally sand, has a radioactivity of 100 to 200 cps, and the redbeds have a radioactivity of 150 to 300 cps.

---

* A playa is defined as the flat-floored bottom of an undrained desert basin that after heavy rains becomes a temporary shallow lake.

7. SUMMARY AND CONCLUSIONS

The radioactivity of the GNOME area ranges from 50 to 600 cps, which is rather low in comparison with other ARMS-I projects. The most radioactive unit in the area is the alluvium in the Pecos River valley, which is 300 to 600 cps. The least radioactive material is Quaternary sand dunes east of the Pecos River where the quartz sand is mostly from 50 to 250 cps.

Permian rocks of Guadalupe age crop out extensively in the Guadalupe and the Delaware Mountains. In the Guadalupe Mountains these rocks have been divided into several formations, but only the contact between the siltstones in the upper part of the Queen Formation and the carbonate rocks of the Seven Rivers Formation coincides with a distinct change of radioactivity, the Queen being higher. The formations in the Guadalupe Mountains are predominantly carbonates (limestones and dolomite), but include anhydrite, sandstone, and siltstome. In the Delaware Mountains all the rocks of Guadalupe age are included in the Delaware Mountain Group, which represents a different facies from that of the formations of equivalent age in the Guadalupe Mountains. The Delaware Mountain Group consists of sandstone and limestone. The predominantly carbonate rocks in the Guadalupe Mountains have a radioactivity of 100 to 600 cps, but most are 200 to 400 cps. The predominantly clastic rocks of the Delaware Mountain Group have a radioactivity of 250 to 550 cps, but most are 350 to 500 cps.

Permian rocks of Ochoa age crop out in the Pecos lowlands and have been divided into the Castile and the Rustler Formations. They are composed principally of anhydrite and carbonate rocks; but the Rustler contains some siltstone and sandstone, which accounts for its slightly higher radioactivity. The Castile ranges from 50 to 450 cps, but most is 100 to 300 cps; the Rustler ranges from 200 to 500 cps, but most is 200 to 300 cps.

The Ogallala Formation of Tertiary age was deposited by coalescing streams and consists mostly of sand, silt, and gravel, but contains some clay, marl, and volcanic ash. This formation is the bedrock over the Llano Estacado portion of the GNOME area, and remnants of the Ogallala occur in the Pecos lowlands. The radioactivity of the Ogallala ranges from 100 to 400 cps. Where Mescalero Ridge, an escarpment of Ogallala, forms the contact between the Quaternary deposits of the Pecos lowlands and the Ogallala of the Llano Estacado, there is a definite change in radioactivity, the Ogallala being about 100 cps higher than the Quaternary deposits.

Within the Pecos lowlands there are small areas of redbeds of Permian and Triassic age and of the Ogallala Formation. At the scale of Figures 3 and 4 and because of the flight line spacing, areas of these rocks cannot be delineated from the Quaternary surficial deposits. On close comparison of the radioactivity charts with aerial photographs it was noted that these areas of redbeds and of Ogallala are about 50 cps higher than the Quaternary surficial deposits and could be delineated by radioactivity with a more detailed aerial survey.

Crow Flats, a large playa or dry lake bed, has a radioactivity of 150 cps higher than its drainage area, but it is not known what radioactive elements are being concentrated in the playa.

REFERENCES

1. F. J. Davis and P. W. Reinhardt, Instrumentation in Aircraft for Radiation Measurements, Nuclear Sci. and Eng., 2 (6): 713-727 (1957).
2. F. J. Davis and P. W. Reinhardt, Radiation Measurements over Simulated Plane Sources, Health Physics, 8: 233-243 (1962).
3. Kermit Larsen, University of California, Los Angeles, written communication (1958).
4. A. Y. Sakakura, Scattered Gamma Rays from Thick Uranium Sources, U. S. Geol. Survey, Bull. No. 1052-A, 50 pp. (1957).
5. J. A. MacKallor, Natural Gamma Aeroradioactivity of the GNOME (Carlsbad) area, New Mexico and Texas, U. S. Geol. Survey Geophys. Inv. Map GP-462 (1964).
6. A. F. Gregory, Geological Interpretation of Aeroradiometric Data, Canada Geol. Survey, Bull. No. 66, 29 pp. (1960).
7. J. L. Meuschke, U. S. Geol. Survey, oral communication (1961).
8. W. L. Russell, The Total Gamma-ray Activity of Sedimentary Rocks as Indicated by Geiger Counter Determinations, Geophysics, 9 (2): 193 (1944).
9. Arthur Bramley and A. K. Brewer, Radioactivity of Potassium, Phy. Rev., 53: 502-505 (1938).
10. H. C. Spicer, Gamma-ray Studies of Potassium Salts and Associated Geologic Formations, U. S. Geol. Survey, Bull. No. 950, p. 143-161 (1946).
11. R. M. Moxham, U. S. Geol. Survey, oral communication (1963).
12. W. G. Harper and L. H. Smith, Soil Survey of the Lovington Area, New Mexico, U. S. Dept. of Agriculture, Bur. of Chemistry and Soils, 20 pp. (1932).
13. C. H. Dane and G. O. Bachman, Preliminary Geologic Map of the Southeastern Part of New Mexico (Scale, 1:380,160), U. S. Geol. Survey, Misc. Geol. Inv. Map I-256 (1958)
14. N. H. Darton, L. W. Stephenson, and J. A. Gardner, Geologic Map of Texas (Scale, 1:500,000), U. S. Geol. Survey (1937).
15. New Mexico Geological Society, Guidebook of Southeastern New Mexico, Fifth Field Conference, correlation chart between p. 38-39 (1954).
16. N. D. Newell, J. K. Rigby, A. G. Fischer, A. J. Whiteman, J. E. Hickox, and J. S. Bradley, The Permian Reef Complex of the Guadalupe Mountains Region, Texas and New Mexico, W. H. Freeman and Co., San Francisco, p. 8-9 (1953).
17. P. J. Hayes and R. L. Koogle, Geology of the Carlsbad Caverns West Quadrangle, New Mexico-Texas, U. S. Geol. Survey, Geol. Quad. Map GQ-112 (1958).
18. R. K. DeFord and G. D. Riggs, Tansill Formation, West Texas and Southeastern New Mexico, Am. Assoc. Petroleum Geol., Bull. No. 25 (9): 1726 (1941).
19. P. B. King, Permian of West Texas and Southeastern New Mexico, Am. Assoc. Petroleum Geol., Bull. No. 26 (4): 535-763 (1942).

20. W. B. Lang, Upper Permian Formation of Delaware Basin of Texas and New Mexico, Am. Assoc. Petroleum Geol., Bull. No. 19 (2): 262-270 (1935).
21. G. B. Richardson, Report of a Reconnaissance in Trans-Pecos, North of the Texas and Pacific Railway, Univ. of Tex. Min. Survey, Bull. No. 9, p. 43 (1904).
22. P. B. King, Geology of the Southern Guadalupe Mountains, Texas U. S. Geol. Survey, Prof. Paper 215, 179 pp. (1948).
23. P. T. Hayes, Geology of the Carlsbad Caverns East Quadrangle, New Mexico, U. S. Geol. Survey, Geol. Quad. Map GQ-98 (1957).
24. C. L. Jones, The Occurrence and Distribution of Potassium Minerals in Southeastern New Mexico in Guidebook of Southeastern New Mexico, Fifth Field Conference, New Mexico Geol. Soc. (1954).
25. P. B. King, Regional Geologic Map of Parts of Culberson and Hudspeth Counties, Texas, U. S. Geol. Survey, Oil and Gas Inv. Prelim. Map 90 (1949).
26. H. W. Hoots, Geology of a Part of Western Texas, and Southeastern New Mexico, with Special Reference to Salt and Potash, U. S. Geol. Survey, Bull. No. 780, p. 97 (1926).
27. J. C. Frye and A. B. Leonard, Correlation of the Ogallala Formation (Neogene) in Western Texas with Type Localities in Nebraska, Bur. Econ. Geol., Univ. of Tex., Rept. Inv. No. 39, 46 pp. (1959).
28. K. G. Books, Aeroradioactivity Survey and Related Surface Geology of Parts of the Los Angeles Region, California (ARMS-I), U. S. Atomic Energy Comm. Report CEX-59.4.16, p. 21 (1962).
29. K. G. Books, Natural Gamma Aeroradioactivity of Parts of the Los Angeles Region, California, U. S. Geol. Survey, Geophys. Inv. Map GP-309 (1962).
30. W. J. Dempsey, U. S. Geol. Survey, written communication (1963).

ADDITIONAL REFERENCES

W. T. Carter, M. W. Beck, H. M. Smith, H. W. Hawker, E. H. Templin, and T. C. Reitch, Soil Survey (Reconnaissance)of the Trans-Pecos Area, Texas, U. S. Dept. Agriculture, Bureau of Chemistry and Soils, No. 35, 66 pp. (1928).

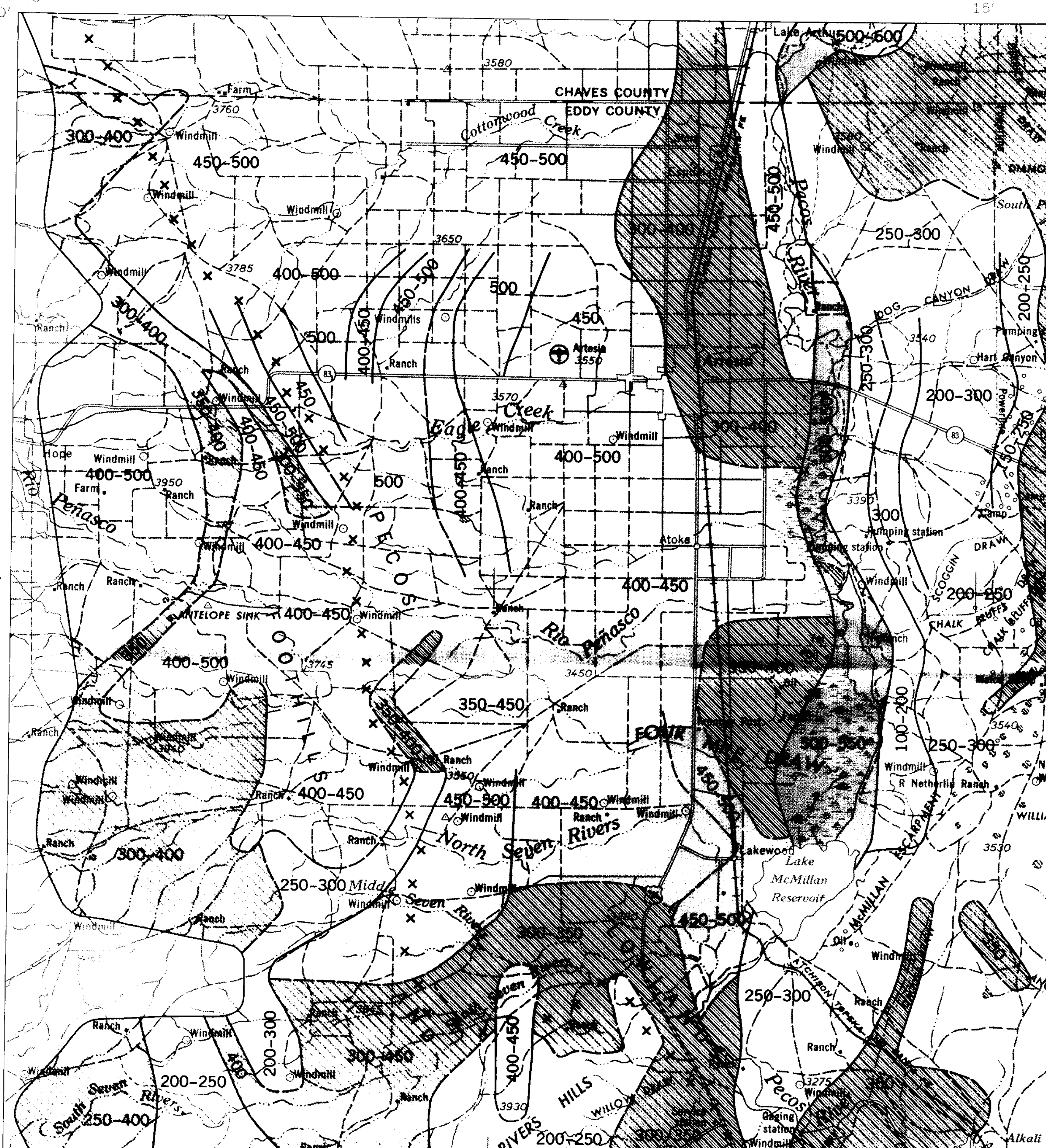
W. T. Carter, M. W. Beck, W. W. Strike, B. H. Hendrickson, R. E. Devereux, H. W. Hawker, and H. V. Geib, Soil Survey (Reconnaissance)of West-Central Texas, U. S. Dept. Agriculture, Bureau of Soils, p. 2041-2131 (1928).

F. J. Davis and P. W. Reinhardt, Extended- and Point-Source Radiometric Program, U. S. Atomic Energy Comm. Report CEX-60.3, 64 pp. (1962).

W. S. Motts, Geology of the West Carlsbad Quadrangle, New Mexico, U. S. Geol. Survey, Geol. Quad. Map GQ-167 (1962).

J. D. Vine, Surface Geology of the Nash Draw Quadrangle, Eddy County, New Mexico, U. S. Geol. Survey, Bull. No. 1141-B, 46 pp. (1963).

DEPARTMENT OF THE INTERIOR (1)
UNITED STATES GEOLOGICAL SURVEY



PF

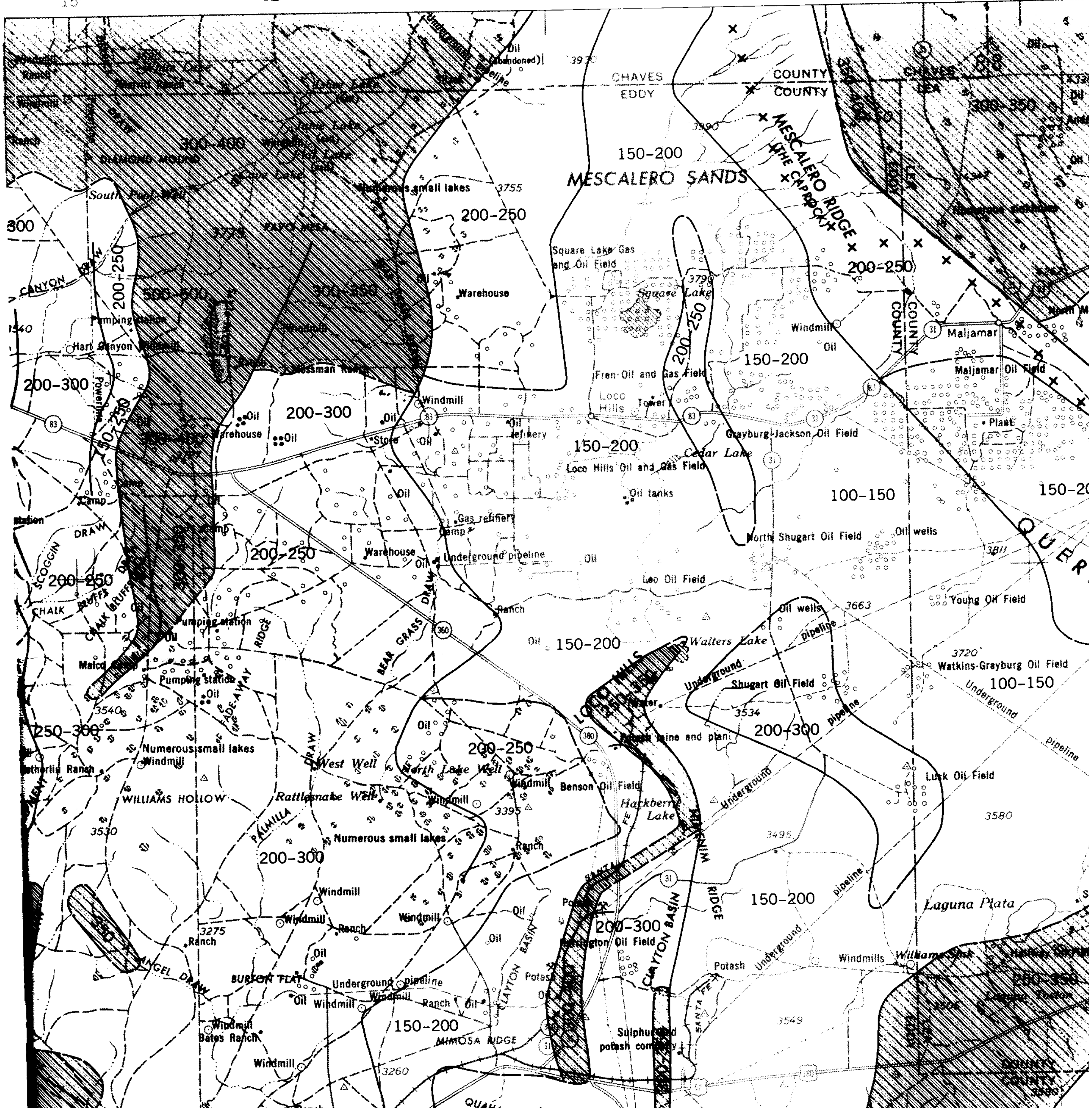
DIVISION

U.S. ATC

2

15'

45'

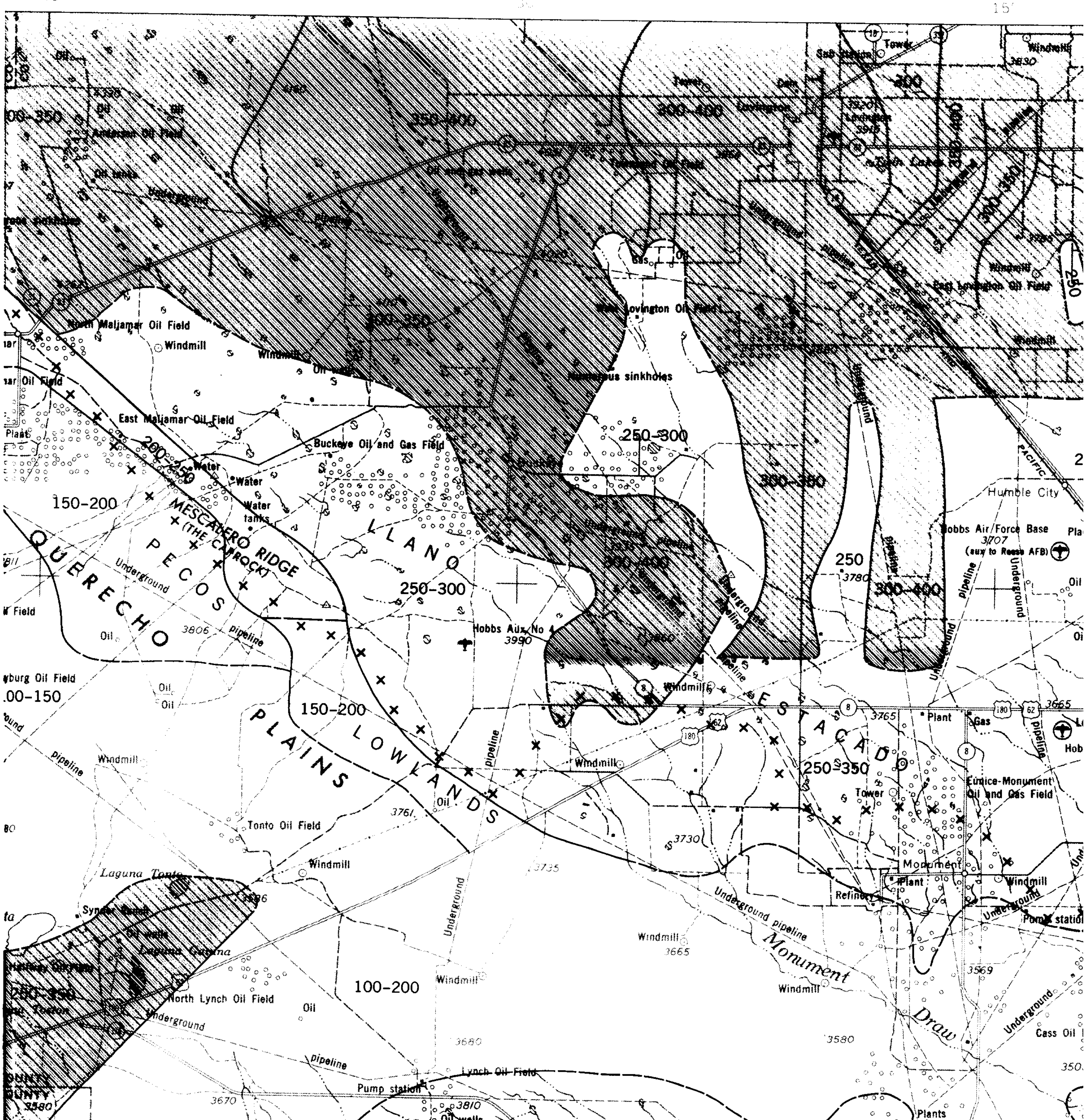


PREPARED IN COOPERATION WITH

DIVISION OF BIOLOGY AND MEDICINE

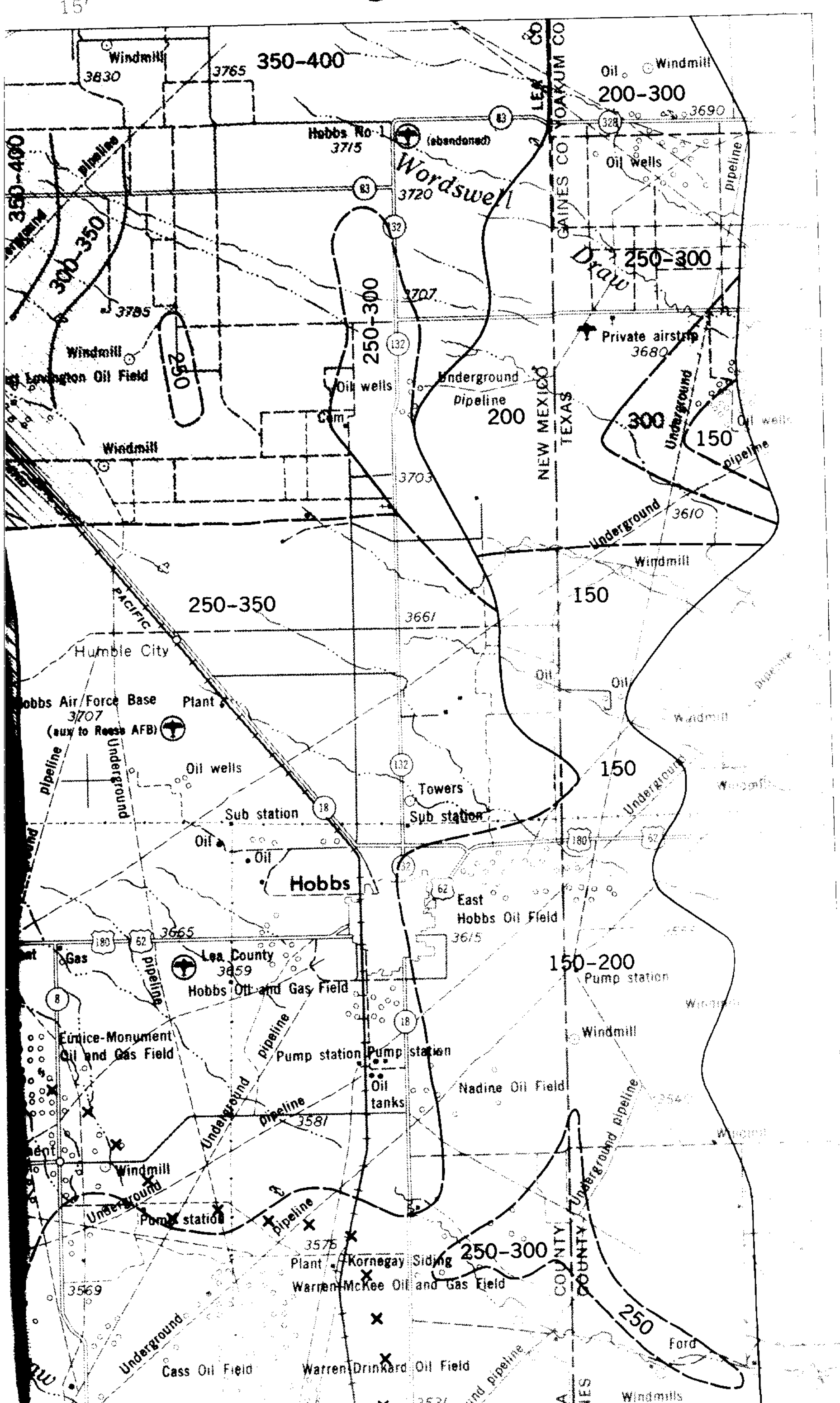
U.S. ATOMIC ENERGY COMMISSION

3



AEC-CEX-5
GEOPHYSICAL INV
MAP GP-
PLATE

4



EXPLANATION

Radioactivity boundary
Dashed where approximately located

× × × × × × ×
Physiographic boundary

500–600

400–500

300–400

200–300

100–200

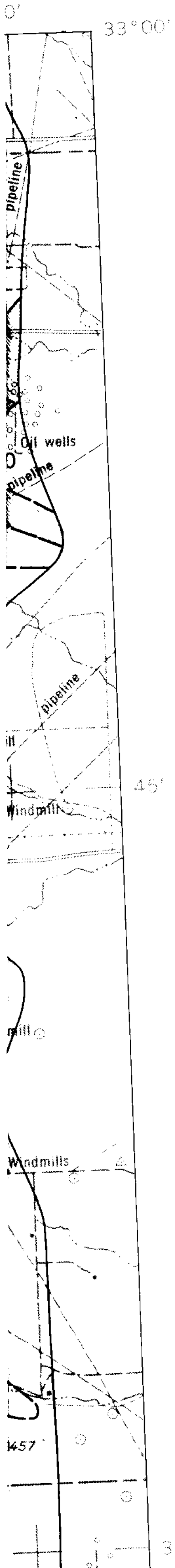
0–100
(over lakes)

Generalized levels of aeroradioactivity in c
second

EXPLANATORY TEXT

An aeroradioactivity survey of ab
square miles around the GNOME t
flown in 1960. The survey was ma
continuously recording scintillatio
equipment (Davis and Reinhardt, 1
stalled in a twin-engine aircraft.

AEC-CEX-59.4.24
GEOPHYSICAL INVESTIGATIONS
MAP GP-462
PLATE 1



5

EXPLANATION

Radioactivity boundary
Dashed where approximately located

× × × × × × ×
Physiographic boundary

500–600

400–500

300–400

200–300

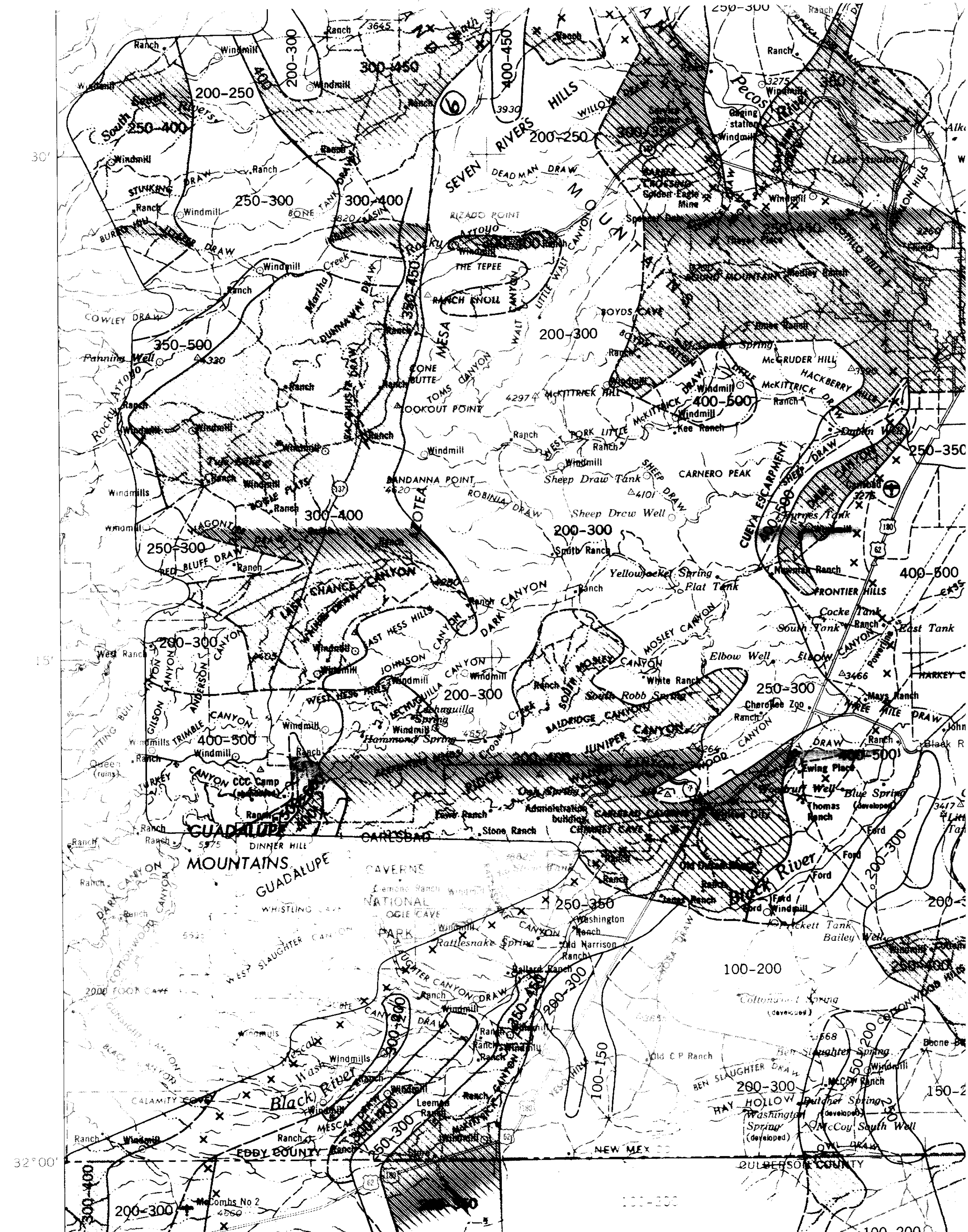
100–200

0–100
(over lakes)

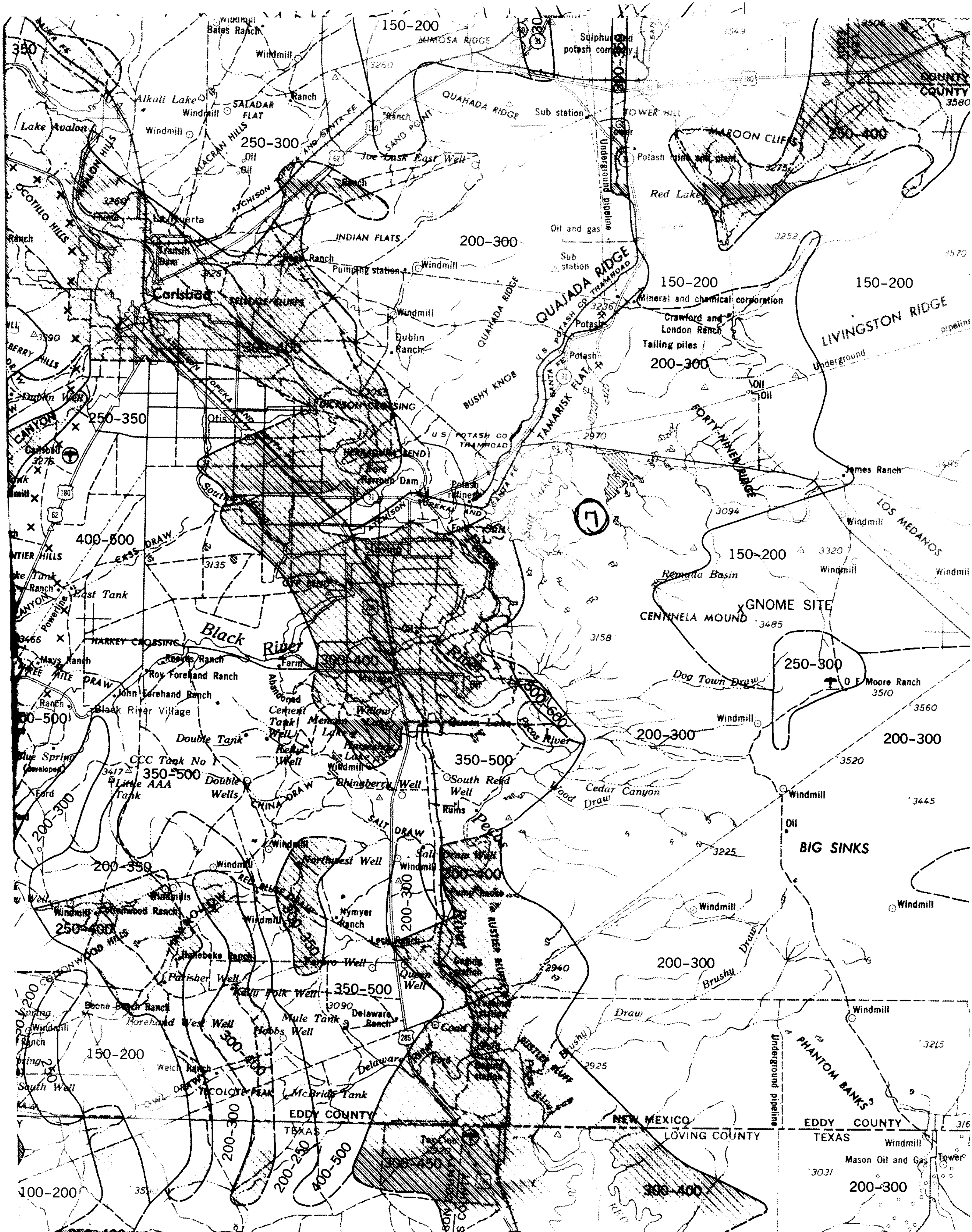
Generalized levels of aeroradioactivity in counts per second

EXPLANATORY TEXT

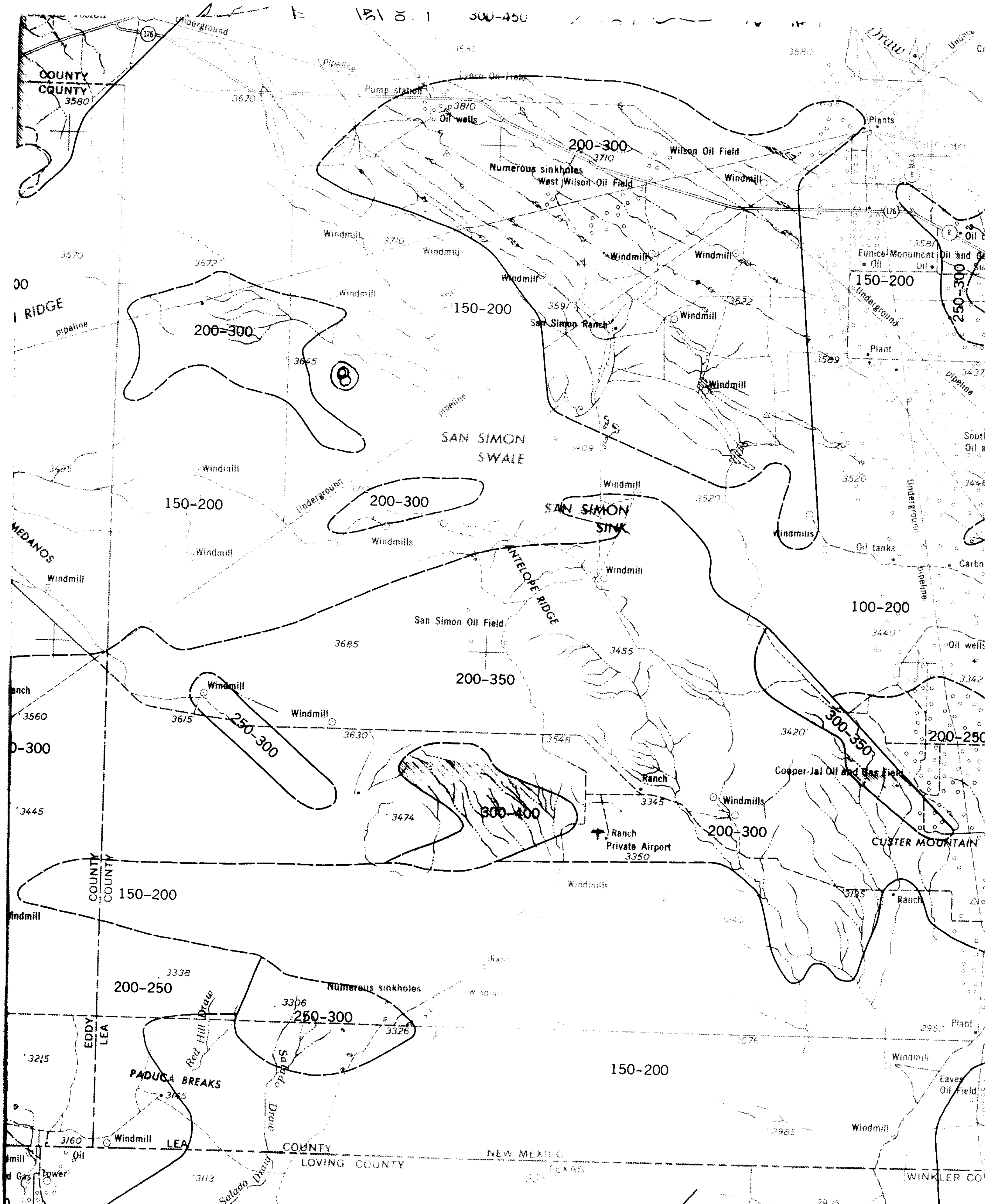
An aeroradioactivity survey of about 7000 square miles around the GNOME test site was flown in 1960. The survey was made with continuously recording scintillation-detection equipment (Davis and Reinhardt, 1957[1]) installed in a twin-engine aircraft. The survey was flown along east-west flight lines approximately 500 feet above the ground. The central one-third of the area was flown at a flight-line spacing of one mile, and the northern and southern parts at a spacing of two miles. Aerial



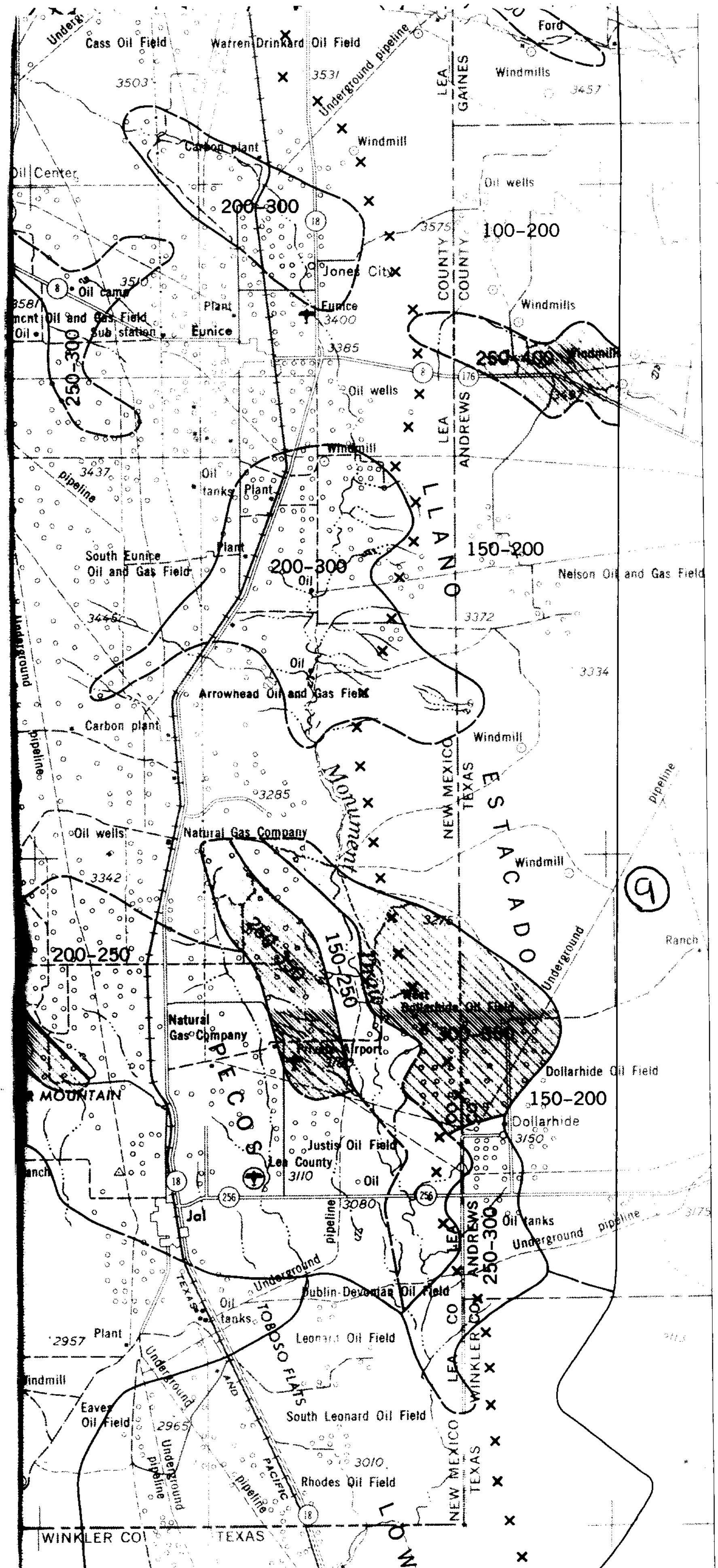
30'
15'
32°00'
SEVEN RIVERS HILLS
MOUNTAINS
GUADALUPE
CARLSBAD
CAVERNS
NATIONAL
PARK
EDDY COUNTY
CULBERSON COUNTY
NEW MEX
Pecos River
Black River
Rocky Arroyo
ROCKY ARROYO
Martha Creek
COWLEY DRAW
STINKING DRAW
BONE TANK DRAW
DEAD MAN DRAW
WILLOW DRAW
McKITTRICK DRAW
LITTLE McKITTRICK DRAW
SHEEP DRAW
SLAUGHTER CANYON
WEST SLAUGHTER CANYON
WALNUT CANYON
DARK CANYON
LAST CHANCE CANYON
JOHNSON CANYON
LECHUGUILLA CANYON
MOSLEY CANYON
SOUTH MOSLEY CANYON
BALDRIDGE CANYON
JUNIPER CANYON
GILSON CANYON
ANDERSON CANYON
TRIMBLE CANYON
TURKEY CANYON
COTTONWOOD CANYON
BEN SLAUGHTER DRAW
HAY HOLLOW
THREE MILE DRAW
ELBOW CANYON
CUEVA ESCARPMENT
CARNERO PEAK
McKITTRICK HILL
McGRUDER HILL
HACKBERRY DRAW
FRONTIER HILLS
EAST HESS HILLS
WEST HESS HILLS
DUNAWAY DRAW
MESA
RANCH KNOLL
THE TEPEE
RIZADO POINT
TOMS CANYON
LOOKOUT POINT
BANDANNA POINT
CONE BUTTE
BOYDS CAVE
DINNER HILL
CCC Camp
Sheep Draw Tank
Sheep Draw Well
Smith Ranch
Yellowjacket Spring
Flat Tank
Cocke Tank
South Tank
East Tank
Elbow Well
White Ranch
South Robb Spring
Cherokee Zoo
Lechuguilla Spring
Hammond Spring
Oak Spring
Stone Ranch
Administration building
Washington Ranch
Rattlesnake Spring
Old Harrison Ranch
Ballard Ranch
Thomas Ranch
Blue Spring
Ewing Place
Woodruff Well
Dublin Well
Fanning Well
Kee Ranch
Prickett Tank
Bailey Well
McCoy Ranch
Butcher Spring
McCoy South Well
Washington Spring (developed)
Old C P Ranch
Ben Slaughter Spring
McCombs No 2
Queen (ruins)
West Ranch
Windmill
Ranch
Gaging station
200-250
250-400
250-300
300-400
300-450
200-300
400-450
350-500
400-500
250-350
100-200
100-150
150-200
300-500



150-200
MIMOSA RIDGE
Bates Ranch
Windmill
Sulphur and potash company
350
Alkali Lake
SALADAR FLAT
Ranch
QUAHADA RIDGE
Sub station
TOWER HILL
Lake Avalon
AVALON HILLS
250-300
ALACRAN HILLS
ATCHISON TOPEKA AND SANTA FE
SAND POINT
Joe Lusk East Well
Underground pipeline
Potash mine and plant
MAROON CLIFFS
250-400
COUNTY
Red Lake
OCOTILLO HILLS
La Huerta
INDIAN FLATS
200-300
Oil and gas
3252
Pumping station
Windmill
Sub station
QUAJADA RIDGE
US POTASH CO TRAMROAD
150-200
Mineral and chemical corporation
150-200
Carlsbad
Crawford and London Ranch
LIVINGSTON RIDGE
Dublin Ranch
QUAHADA RIDGE
Potash
Tailing piles
200-300
Underground
300-400
Dublin Well
BUSHY KNOB
TAMARISK FLAT
250-350
CANYON
Otis
US POTASH CO TRAMROAD
2970
Carlsbad
Potash refinery
FORTY-NINER RIDGE
James Ranch
Avalon Dam
3094
LOS MEDANOS
Salt Lake
7
400-500
CASS DRAW
3135
150-200
3320
East Tank
Remuda Basin
Windmill
GNOME SITE
CENTINELA MOUND
3485
Black River
HARKEY CROSSING
3158
Reeves Ranch
Farm
300-400
Roy Forehand Ranch
John Forehand Ranch
Dog Town Draw
250-300
O F Moore Ranch
3510
Black River Village
Abandoned Cement Tank Well
Willow Lake
Queen Lake
Pecos River
300-600
3560
Double Tank
Windmill
200-300
200-300
CCC Tank No 1
350-500
350-500
3520
Little AAA Tank
Double Wells
CHINA DRAW
Chinaberry Well
South Reed Well
Wood Draw
Cedar Canyon
Windmill
200-300
Ruins
3445
SALT DRAW
Oil
BIG SINKS
200-350
Windmill
Northwest Well
Salt Draw Well
3225
Windmill
300-400
Windmills
Cottonwood Ranch
250-400
COTTONWOOD HILLS
Nymyer Ranch
200-300
Windmill
Windmill
Hollebeke Ranch
Navajo Well
Queen Well
2940
200-300
Brushy Draw
Parisher Well
Kelly Polk Well
350-500
3090
Delaware Ranch
Boone Ranch
Forehand West Well
300-400
Mule Tank
Hobbs Well
Windmill
Draw
Underground pipeline
PHANTOM BANKS
3215
150-200
Welch Ranch
Delaware River
2925
South Well
TECOLOTE PEAK
McBride Tank
EDDY COUNTY
NEW MEXICO
EDDY COUNTY
TEXAS
LOVING COUNTY
TEXAS
Windmill
200-300
200-250
400-500
300-450
300-400
Mason Oil and Gas
Tower
3031
100-200
200-300



COUNTY
COUNTY
3580
Underground
pipeline
3580
Lynch Oil Field
Pump station
3670
3810
Oil wells
Plants
200-300
3710
Wilson Oil Field
Numerous sinkholes
West Wilson Oil Field
Windmill
Windmill
3710
Windmill
Windmill
Windmill
3570
3672
Eunice-Monument Oil and Gas
Oil
150-200
Windmill
Windmill
150-200
3591
San Simon Ranch
3622
Windmill
RIDGE
pipeline
200-300
Underground
250-300
Plant
3645
3589
3437
pipeline
Windmill
pipeline
SAN SIMON
SWALE
3409
3495
Windmill
150-200
Underground
200-300
Windmill
SAN SIMON
SINK
3520
3520
Underground
MEDANOS
Windmills
Windmill
Windmills
Oil tanks
Windmill
Windmill
ANTELOPE RIDGE
pipeline
100-200
San Simon Oil Field
3440
3685
Oil wells
3455
200-350
3560
Windmill
Windmill
3615
250-300
3630
3548
3420
300-350
200-250
-300
Cooper-Jal Oil and Gas Field
Ranch
3445
3474
300-400
3345
Windmills
200-300
Ranch
Private Airport
3350
CUSTER MOUNTAIN
Windmills
COUNTY
COUNTY
150-200
3195
Ranch
Windmill
3338
200-250
Numerous sinkholes
3306
250-300
3326
Red Hill Draw
EDDY
LEA
3215
PADUCA BREAKS
Salado Draw
3165
2957
Plant
Windmill
Eaves Oil Field
150-200
2985
Windmill
3160
Windmill
LEA
COUNTY
Oil
Tower
LOVING COUNTY
NEW MEXICO
TEXAS
3113
Salado Draw
WINKLER CO



continuously recording scintillation-de equipment (Davis and Reinhardt, 1957[1] stalled in a twin-engine aircraft. The was flown along east-west flight lines a imately 500 feet above the ground. Th one-third of the area was flown at a flig spacing of one mile, and the northern a southern parts at a spacing of two mile photographs were used for pilot guidan the flight path of the aircraft was reco a continuous-strip-film camera. When craft passed over recognizable feature cial edge marks were made simultaneo the film and on the radioactivity and th eter charts.

The radioactivity data were compens for deviations from the 500-foot survey elevation by signals from the radar alti The scintillation equipment measures gamma radiation with energy levels gr than 50 kev (thousand electron volts), a results are recorded in cps (counts pe The effective area of response of the s lation equipment at an elevation of 500 above the ground is approximately 100 in diameter.

The gamma-ray flux at 500 feet above ground has three principal components radiation, radionuclides in the air, and nuclides in the upper few inches of sur material. The cosmic component is m sured two or more times daily at 2000 above the ground, and the scintillation equipment is adjusted to remove the co effects from the radioactivity record.

The component due to radionuclides i air (mostly radon daughter products) a feet above the ground is difficult to eva It is affected greatly by meteorological ditions; but if no survey lines are flown ing conditions of extreme inversion or and immediately after thunder showers component does not obscure radioactiv levels that reflect changes in the groun ponent.

The ground component consists of ga rays from natural radionuclides (princi members of the uranium and thorium r active decay series and potassium-40) from fallout from atomic testing. The radioactivity measured in the GNOME a quite low, and the component due to fal if any, is negligible. The distribution naturally occurring radionuclides in th continuously recording scintillation-detection equipment (Davis and Reinhardt, 1957[1]) installed in a twin-engine aircraft. The survey was flown along east-west flight lines approximately 500 feet above the ground. The central one-third of the area was flown at a flight-line spacing of one mile, and the northern and southern parts at a spacing of two miles. Aerial photographs were used for pilot guidance, and the flight path of the aircraft was recorded with a continuous-strip-film camera. When the aircraft passed over recognizable features, fiducial edge marks were made simultaneously on the film and on the radioactivity and the altimeter charts.

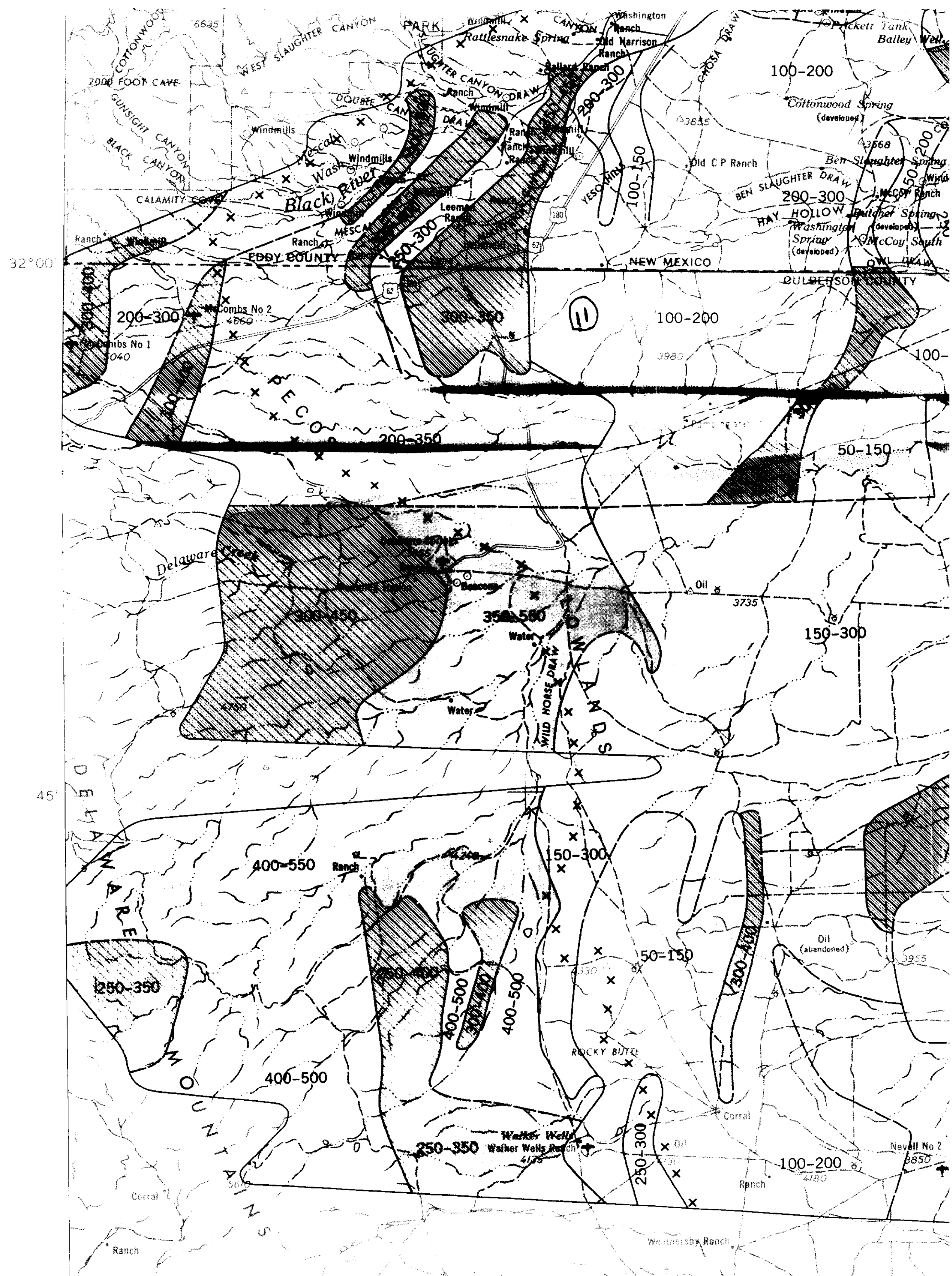
10

The radioactivity data were compensated for deviations from the 500-foot surveying elevation by signals from the radar altimeter. The scintillation equipment measures only gamma radiation with energy levels greater than 50 kev (thousand electron volts), and the results are recorded in cps (counts per second). The effective area of response of the scintillation equipment at an elevation of 500 feet above the ground is approximately 1000 feet in diameter.

The gamma-ray flux at 500 feet above the ground has three principal components: cosmic radiation, radionuclides in the air, and radionuclides in the upper few inches of surficial material. The cosmic component is measured two or more times daily at 2000 feet above the ground, and the scintillation equipment is adjusted to remove the cosmic effects from the radioactivity record.

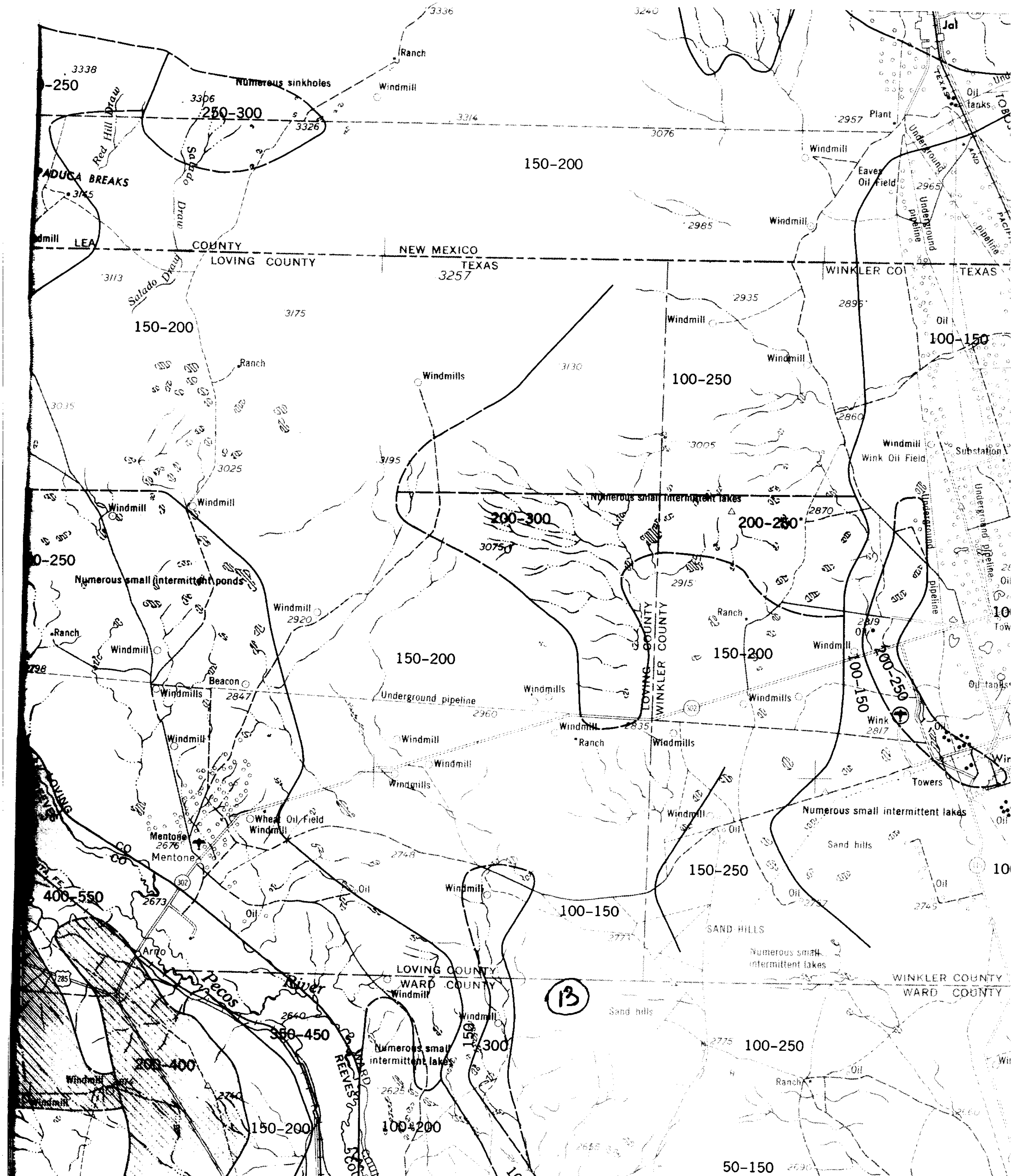
The component due to radionuclides in the air (mostly radon daughter products) at 500 feet above the ground is difficult to evaluate. It is affected greatly by meteorological conditions; but if no survey lines are flown during conditions of extreme inversion or during and immediately after thunder showers, the air component does not obscure radioactivity levels that reflect changes in the ground component.

The ground component consists of gamma rays from natural radionuclides (principally members of the uranium and thorium radioactive decay series and potassium-40) and from fallout from atomic testing. The total radioactivity measured in the GNOME area is quite low, and the component due to fallout, if any, is negligible.

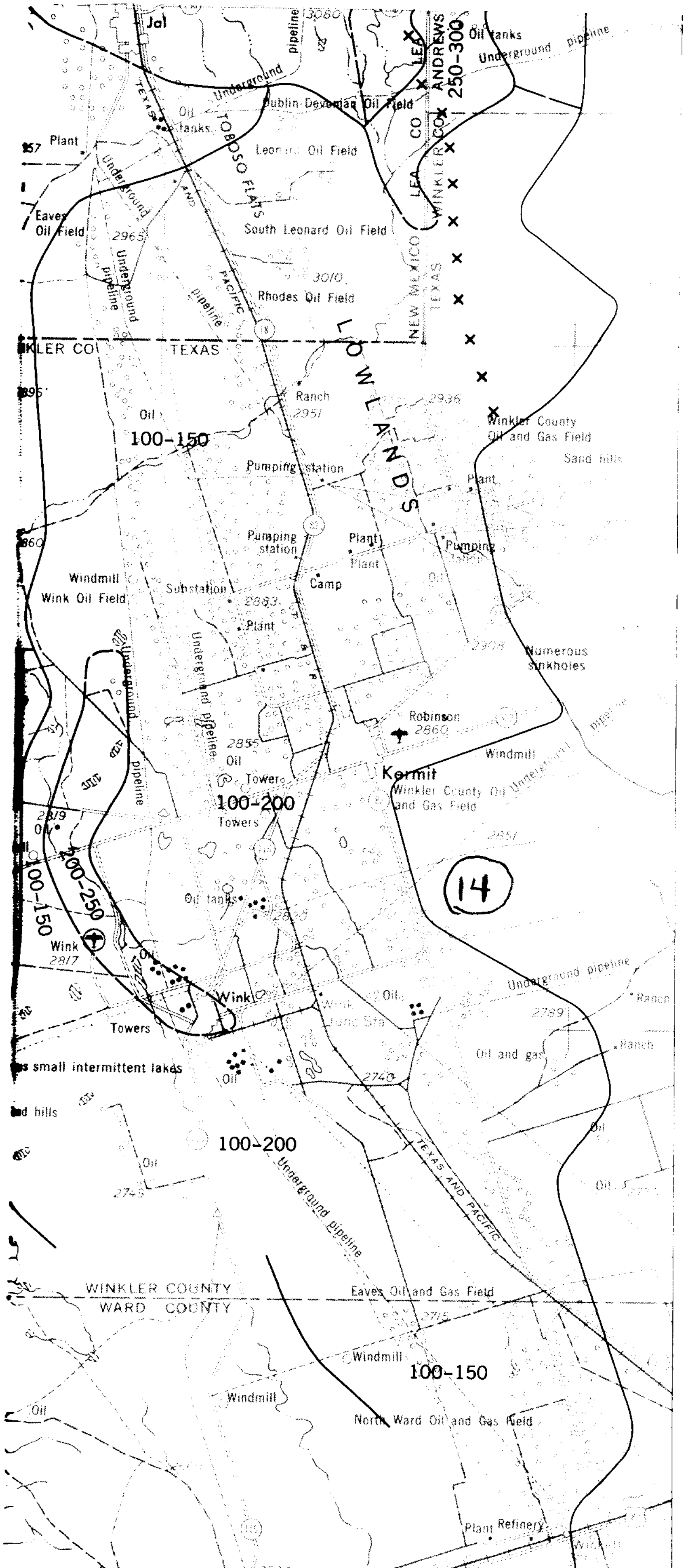


32°00'
45'
COTTONWOOD
2000 FOOT CAVE
GUNSIGHT CANYON
BLACK CANYON
CALAMITY COVE
WEST SLAUGHTER CANYON
PARK
Rattlesnake Spring
Washington Ranch
Old Narrison Ranch
Ballard Ranch
SLAUGHTER CANYON DRAW
DOUBLE CANYON
Windmills
Mescal Wash
Black River
EDDY COUNTY
NEW MEXICO
CULBERSON COUNTY
CHOSA DRAW
YESO HILLS
Old C P Ranch
BEN SLAUGHTER DRAW
HAY HOLLOW
Washington Spring (developed)
Cottonwood Spring (developed)
Ben Slaughter Spring
McCombs No 2
4660
McCombs No 1
Bailey Well
Prickett Tank
100-200
200-300
100-150
150-300
300-350
300-400
50-300
400
200-350
50-150
Delaware Creek
300-450
350-550
Water
WILD HORSE DRAW
LOWLANDS
PECOS
Oil
3735
3980
DELAWARE MOUNTAINS
400-550
Ranch
150-300
50-150
300-400
Oil (abandoned)
3955
250-350
250-400
400-500
300-400
ROCKY BUTTE
Corral
250-350
Walker Wells
Walker Wells Ranch
250-300
100-200
Nevell No 2
3850
4180
Weathersby Ranch

200-400
350-500
200-300
150-200
EDDY COUNTY
NEW MEXICO
TEXAS
LOVING COUNTY
EDDY
LEA
PHANTOM BANKS
Underground pipeline
Mason Oil and Gas
300-450
300-400
400-500
200-250
Delaware Creek
200-350
12
Red Bluff
400-500
250-450
Pecos River
Windmill
Mule Tank
Delaware Ranch
Nymyer Ranch
McBride Tank
Brushy Draw
Oil tanks
200-350
150-200
250-350
250-450
150-200
300-350
300-450
150-300
200-300
INCLINE DRAW



Numerous sinkholes
250-300
Red Hill Draw
Salado Draw
Ranch
Windmill
150-200
LEA COUNTY
NEW MEXICO
LOVING COUNTY
TEXAS
WINKLER CO
TEXAS
Jal
Oil tanks
Plant
Underground pipeline
Eaves Oil Field
100-150
100-250
Windmills
Numerous small intermittent lakes
200-300
200-250
Wink Oil Field
Substation
Numerous small intermittent ponds
Beacon
Underground pipeline
LOVING COUNTY
WINKLER COUNTY
150-200
100-150
200-250
Wink
Towers
Numerous small intermittent lakes
Sand hills
Wheat Oil Field
Mentone
150-250
100-150
400-550
SAND HILLS
Pecos River
Arno
LOVING COUNTY
WARD COUNTY
WINKLER COUNTY
WARD COUNTY
13
Sand hills
350-450
200-400
150
300
Numerous small intermittent lakes
100-250
REEVES
WARD
150-200
100-200
50-150

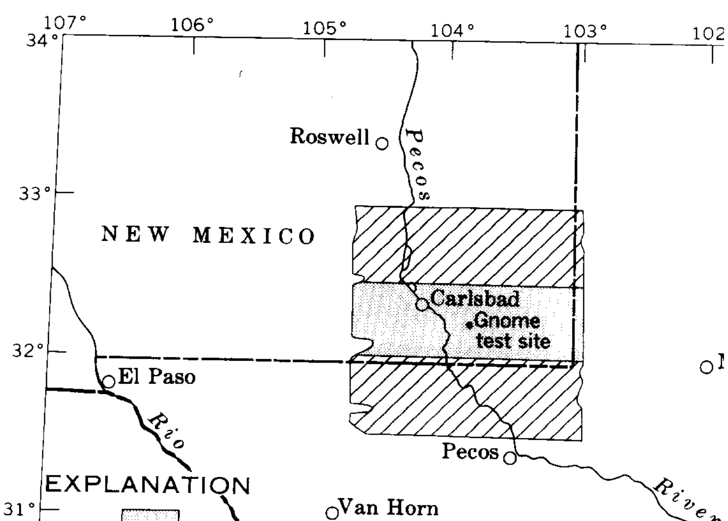


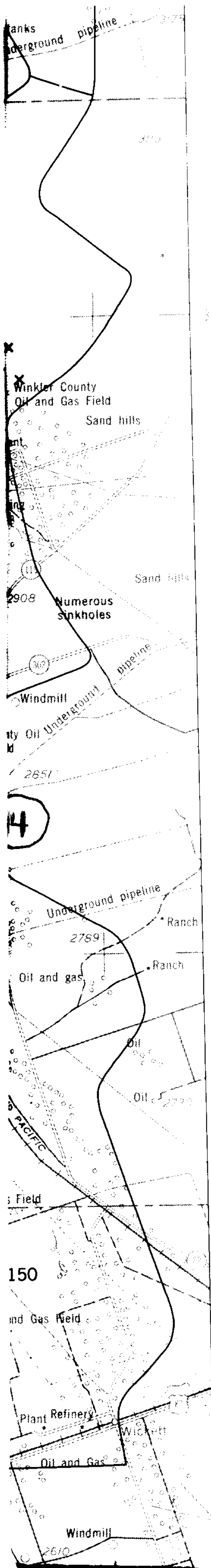
and immediately after thunder showers,
component does not obscure radioactivi
levels that reflect changes in the grounc
ponent.

The ground component consists of gam
rays from natural radionuclides (princip
members of the uranium and thorium ra
active decay series and potassium-40) a
from fallout from atomic testing. The t
radioactivity measured in the GNOME a
quite low, and the component due to fall
if any, is negligible. The distribution o
naturally occurring radionuclides in the
ficial rocks and soil is reflected in the r
sured radioactivity, and in some areas
be correlated directly with geology.

Some of the small radioactivity breaks
contacts between areas of different radi
become obscure or disappear, and the c
as shown on the map, terminate without
ing an area of distinct radioactivity. Th
explanation is that in places there is a s
boundary between two types of surficial
and in other places the surficial materia
mixed within a transitional zone between
types of surficial material. In addition t
small radioactivity units shown on the m
entire area has been divided by 100 cps
ments into six generalized levels of radi
activity shown by green patterns on the r

[1]Davis, F. J., and Reinhardt, P. W.,
Instrumentation in aircraft for radiation
surements: Nuclear Sci. and Eng., v. 2
6, p. 713-727.





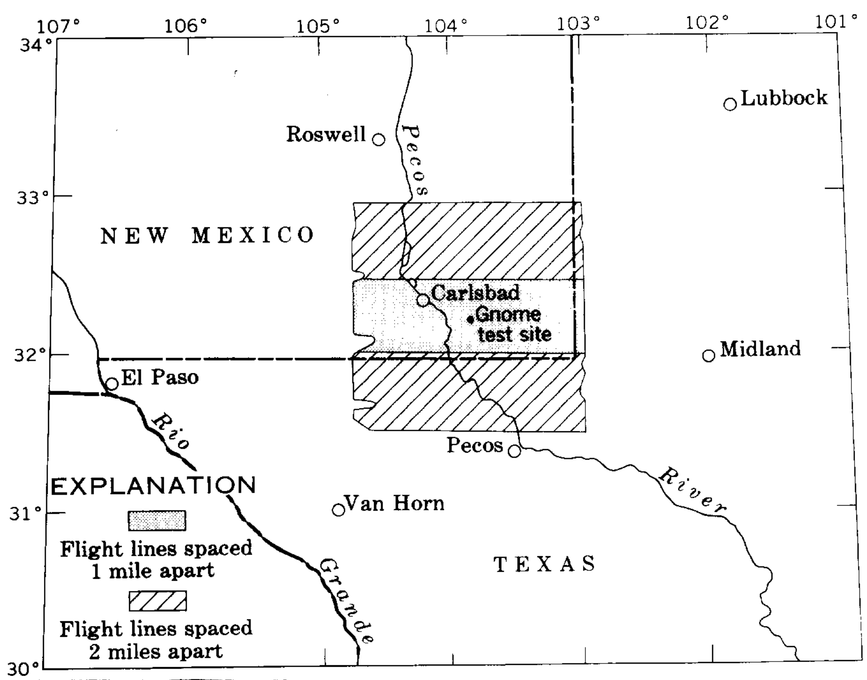
and immediately after thunder showers, the air component does not obscure radioactivity levels that reflect changes in the ground component.

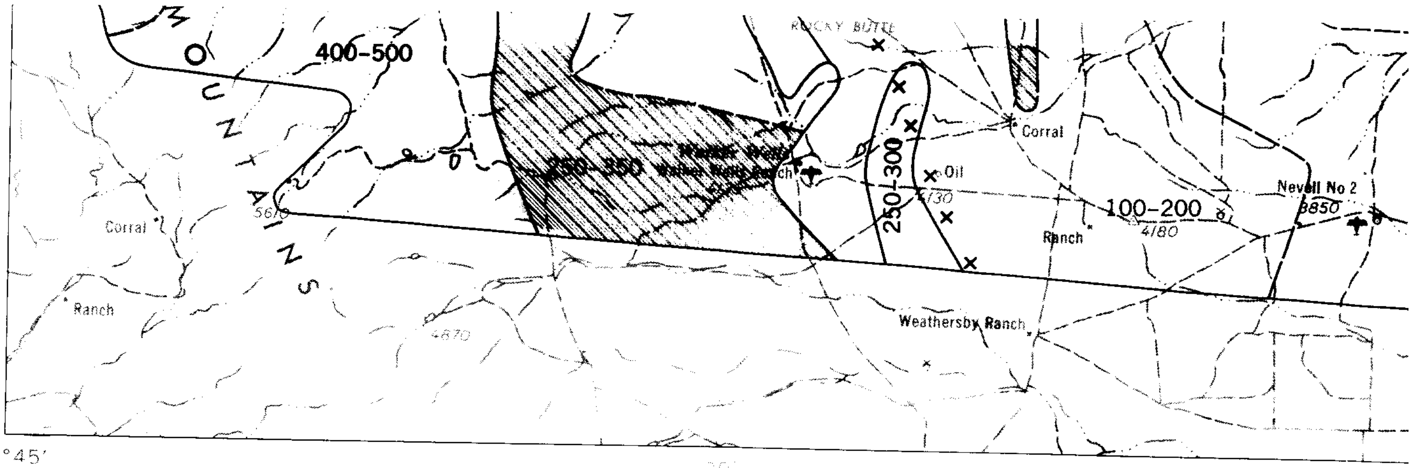
The ground component consists of gamma rays from natural radionuclides (principally members of the uranium and thorium radioactive decay series and potassium-40) and from fallout from atomic testing. The total radioactivity measured in the GNOME area is quite low, and the component due to fallout, if any, is negligible. The distribution of the naturally occurring radionuclides in the surficial rocks and soil is reflected in the measured radioactivity, and in some areas can be correlated directly with geology.

Some of the small radioactivity breaks or contacts between areas of different radioactivity become obscure or disappear, and the contacts, as shown on the map, terminate without enclosing an area of distinct radioactivity. The usual explanation is that in places there is a sharp boundary between two types of surficial material and in other places the surficial material is mixed within a transitional zone between the two types of surficial material. In addition to the small radioactivity units shown on the map, the entire area has been divided by 100 cps increments into six generalized levels of radioactivity shown by green patterns on the map.

15

[1]Davis, F. J., and Reinhardt, P. W., 1957, Instrumentation in aircraft for radiation measurements: Nuclear Sci. and Eng., v. 2, no. 6, p. 713-727.

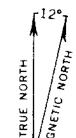




31°30'
104°45'

Base from U.S. Geological Survey 1:250,000 series quadrangles
Carlsbad, Hobbs, Pecos, and Van Horn, 1954

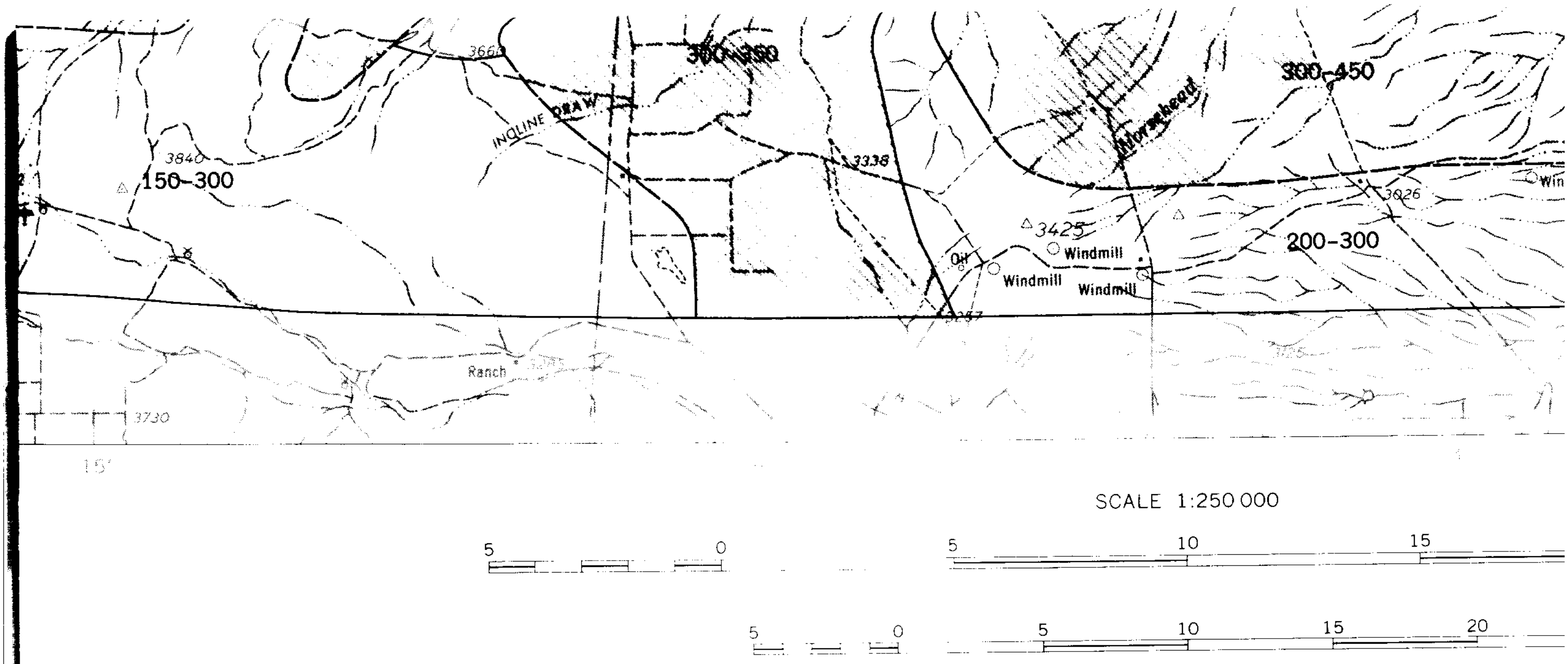
16



APPROXIMATE MEAN
DECLINATION, 1964

PLATE 1 NA

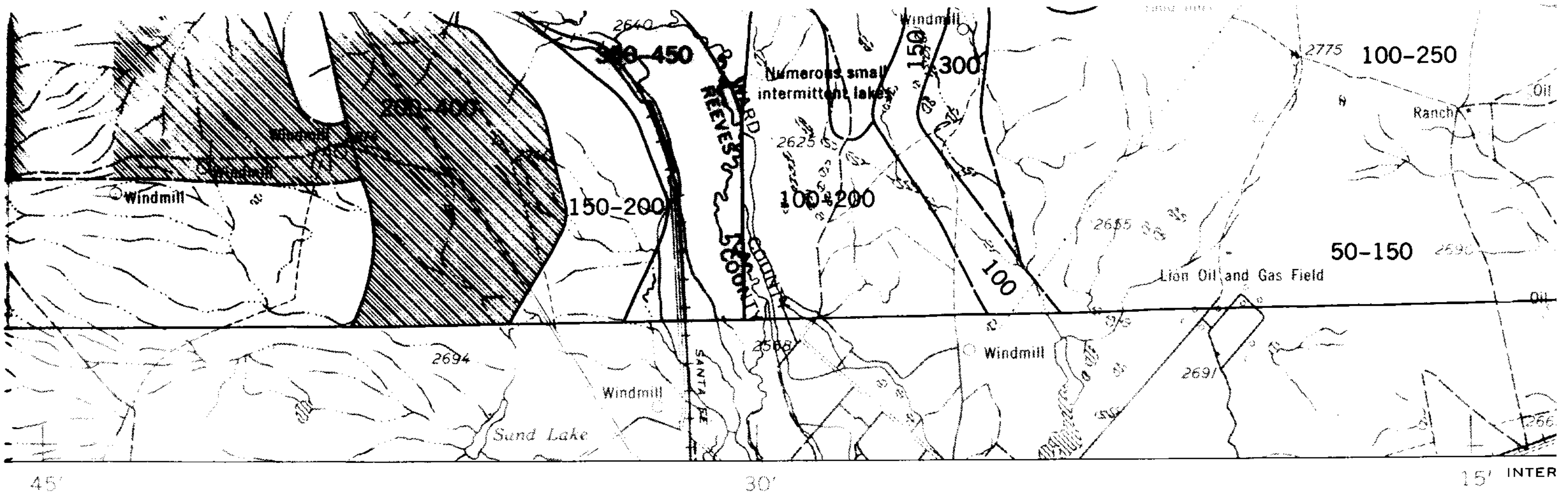
AEC-CEX-59.4.24
GEOPHYSICAL INVESTIGATIONS
MAP GP-462



NATURAL GAMMA AERORADIOACTIVITY OF T

(17)

Jules



5 20 25 MILES

20 25 KILOMETERS

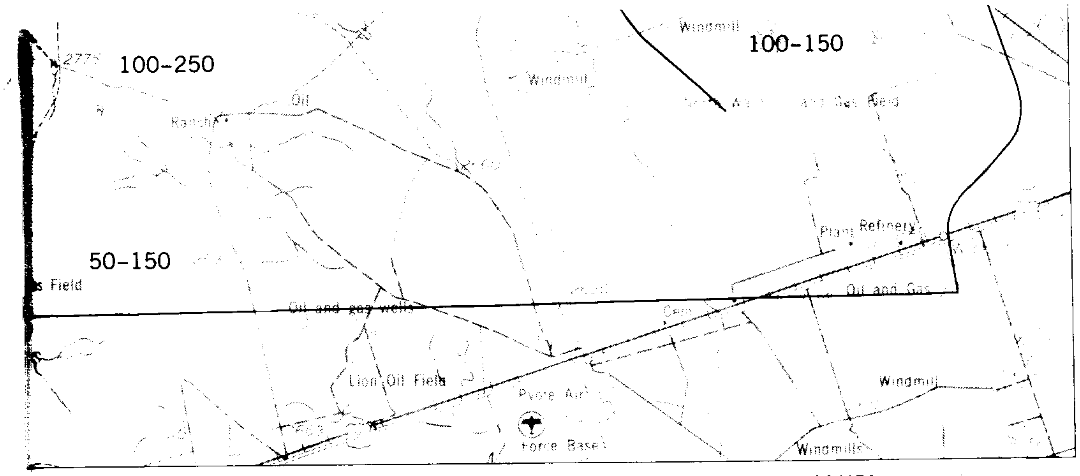
18

OF THE GNOME (CARLSBAD) AREA, NEW M

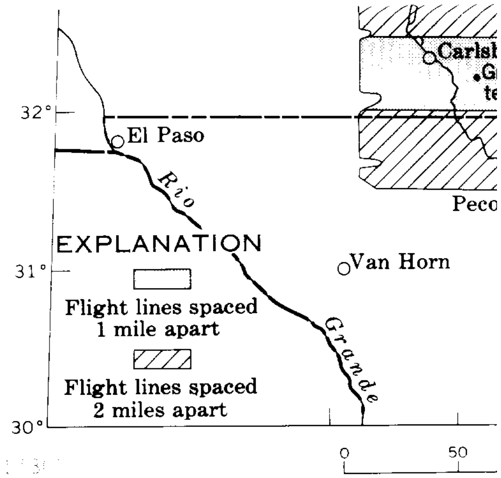
By

Jules A. MacKallor

1964



INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1964—G64176



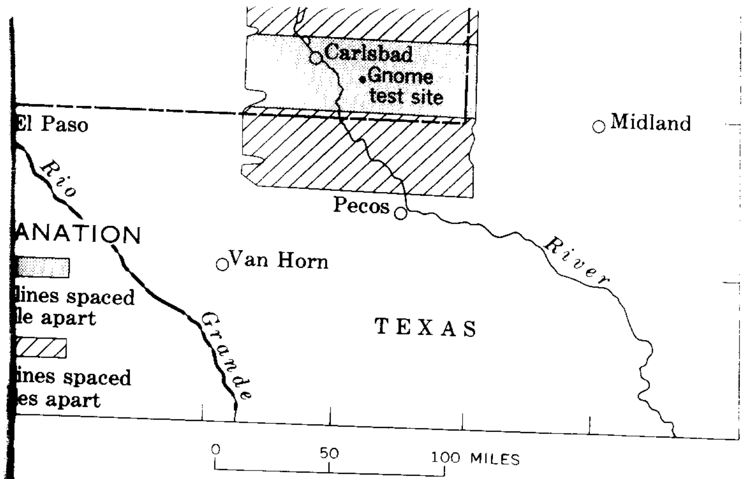
INDEX MAP SHOWING AR

Aeroradioactivity survey made at 500 feet above the ground under the direction of J. L. Meuschke, 1960

(19)

NEW MEXICO AND TEXAS

Map obtainable from U.S. Geolog



X MAP SHOWING AREA OF THIS REPORT

20

Map obtainable from U.S. Geological Survey, Washington, D. C. 20242